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A METHODOLOGY FOR EVALUATING THE IMPACT OF RAILROAD ABANDONMENT ON RURAL HIGHWAYS

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PURDUE UNIVERSITY
INDIANA STATE HIGHWAY COMMISSION

Final Report

A METHODOLOGY FOR EVALUATING THE IMPACT OF RAILROAD ABANDONMENT ON RURAL HIGHWAYS

TO: J. F. McLaughlin, Director
Joint Highway Research Project

January 13, 1976

File: 3-3-40

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

Project: C-36-54NN

The attached Final Report is submitted on the JHRP Research Study titled "Impact of Railroad Abandonment on Highways in Indiana". The Report is titled "A Methodology for Evaluating the Impact of Railroad Abandonment on Rural Highways". The Report has been authored by Mr. Lynn O. Purnell, Graduate Instructor in Research on our staff, under the direction of Professor K. C. Sinha.

The Report includes development of a methodology for the impact of railroad abandonment on existing highways and bridges and application of the procedure to two case studies in Indiana. The indicated effects are in increased deterioration of some pavements and hence a required additional amount of resurfacing material and in increased emphasis on replacement of inadequate bridges and traffic congestion in some areas. A dollar effect of the additional resurfacing is calculated for the two case studies and emphasizes the increased financial needs which railroad abandonment will have on rural highways in Indiana.

The Report is submitted as fulfillment of the objectives of the research.

Respectfully submitted,

Harold L. Michael

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by

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ABSTRACT

Purnell, Lynn Omega. M.S.C.E., Purdue University, December 1975. A Methodology for Evaluating the Impact of Railroad Abandonment on Rural Highways. Major Professor: Kumares C. Sinha.

The purpose of this research effort was to investigate the possible impact of railroad service discontinuance on rural highways and bridges in Indiana. The objectives of the study were accomplished by the development of an evaluative methodology that can be employed by railroad shipper groups, local governments, and state agencies for estimating the public costs associated with a highway's providing equivalent service to a railroad facility which is being considered for abandonment.

The adopted methodology encompasses procedures to be utilized for determining railroad abandonment's effects on both highway pavements and bridges. With regard to highway pavements, formulas were developed which express rail service discontinuance's impact on a rural highway in terms of additional thickness of asphaltic concrete overlay. In order to minimize the number of computations required in using these formulas, graphs were prepared that would provide directly the amount of additional bituminous concrete overlay which can be attributed to a railroad line's closing.

The procedure for estimating possible effects of increased truck traffic on rural highway bridges involves analyzing data obtained from secondary sources of information in conjunction with personal inspection of structures likely to be affected by railroad abandonment.

In addition to the aforementioned procedures, the evaluative methodology includes not only techniques to be used for meeting the system's data requirements but also a means of determining the financial impact of a branch line's closure on affected rural highways.

Following development of the methodology, two areas within Indiana which are confronted with possible loss of railroad service were selected as procedural demonstrations. As a means of determining what transportation alternatives to direct railroad service were being considered by rail users in the case study areas, thirty-three shippers in the two regions were interviewed. A major conclusion reached from the interviews involves the shippers' expressed desire for direct rail accessibility despite the fact that many have discontinued use of the mode. Shippers in the two areas were observed to fear the loss of flexibility associated with branch line abandonment.

From utilizing the adopted methodology for the case study regions, it was found that railroad service discontinuance on the North Vernon to Madison branch line could result in a need of up to 0.60 inches of additional asphaltic concrete overlay for affected highway sections in Jennings, Jefferson, and Scott counties. Furthermore, it was learned from the rural bridge analysis for these same three counties that ten of the nineteen structures located on affected highway sections are currently in need of replacement or repair; thus, it was concluded that abandonment would have a serious impact on the structurally deficient bridges which predominate on the highways undergoing analysis.

For the aforementioned three counties, public costs incurred from resurfacing those highway sections that would be affected to the greatest extent were determined.

By using the increases in required overlay thickness which were determined from the impact graphs, the added cost of repaving the affected highway sections was determined to be $145,200. This figure represents only a first approximation to the financial impact of abandoning the North Vernon to Madison branch line.

PART ONE

INTRODUCTION

BACKGROUND INFORMATION ON THE RAILROADS' DECLINE AND PLANS FOR REORGANIZATION

The Decline of Railroads in the United States

During the nineteenth century and the first fifty years of the twentieth century, the railroad was the predominant mode of transportation within the United States. From its modest beginning in 1835 as a 767-mile system confined simply to states situated along the Atlantic seaboard, the national rail system had expanded to a 254,000-mile intercontinental network by World War I (35)*. The railroad is considered to be the first modern means of transportation to develop within this nation; thus, the mode enjoyed an advantage of being able to grow without pressure from competitive modes of travel. In the absence of significant competition, the railroad offered its patrons a variety of transportation services, including the movement of both freight and passengers. However, during the past thirty years, the railroad's prominence in freight and passenger transportation has deteriorated, caused, in part, by the rapid evolution of more popular competing modes of transportation.

By comparing several railroad industry statistics for two years, 1947 and 1973, the extent of the industry's decline can be shown rather vividly. Although a tremendous increase in passenger travel occurred in the years from 1947 to 1973, American railroads suffered an 80 percent reduction in revenue passenger miles. During this same period of time, the rail industry's

*Numbers in parentheses refer to entries in the List of References.

share of the intercity freight market dwindled, from 67 percent in 1947 to only 39 percent in 1973 (35). During these 26 years when the American gross national product (GNP) increased nearly 170 percent and national industrial production climbed over 219 percent, railroads experienced a mere 30 percent increase in total rail revenue ton-miles. In contrast to other transportation modes which have undergone considerable expansion in services and facilities, the railroad industry has continuously diminished over the years in reaching its current network of approximately 200,000 line-miles.

As suggested by the statistics mentioned in the previous paragraph, the economic picture of the rail industry is particularly bleak. Railroad earnings in 1973 represented only 75 percent of the amount earned by the industry in 1947, after making adjustments for the inflation which occurred during this time period. Rail net income, expressed as a percentage of equity for the rail industry as a whole, was less than 2 percent in 1973 (35). The railroads' poor fiscal condition has caused other serious problems to occur. Unable to generate enough money to meet necessary capital requirements, and without a sufficient return on investment to permit the sale of common stock, the railroads have been forced to forego much-needed track and facility maintenance. Consequently, the industry has become burdened with an old physical plant which is expensive to operate, and the plant is likely to cause additional shippers to cease railroad operations. The railroad industry is currently in the midst of an ever-widening downward spiral, characterized by declining revenue which creates the need for deferred maintenance, followed by additional loss of revenue as users look for a more efficient means of moving commodities.

The preceding two paragraphs describe only briefly the unfortunate status of this country's rail network. Every railroad system in the United States is facing the same problem of declining patronage with its accompanying decrease in revenue. Nevertheless, the aforementioned problems are particularly acute in one section of the country, a region generally described as the Northeastern United States. This region is bordered by Canada to the north and by Virginia, West Virginia, and the Ohio River to the south. It is an area bounded by the Atlantic Ocean to the east and by Michigan and Illinois to the west (35). Confronted with the impending bankruptcy of eight railroad companies in the region known as the Northeastern United States, the United States Congress responded by drafting the Regional Rail Reorganization Act of 1973 (23). Since Indiana is included in the area coming under jurisdiction of the 1973 Act, the following section describes in greater detail the plight of the Northeastern railroads.

The Railroad Situation in the Northeast and Midwest

The section of the nation addressed by the U. S. Congress in the Regional Rail Reorganization Act of 1973 (hereafter referred to as the Act) includes most of America's population centers and over one-half of its economic activity (35). Over 55 percent of the nation's manufacturing plants and nearly 60 percent of the country's employees engaged in manufacturing are located within the Region, the name attached to the affected area (the Northeastern United States) by the Act itself (35). The 17 states comprising the Region are Connecticut, Delaware, Indiana, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia. In addition, the

provisions of the Act also apply to the District of Columbia. More than 2.5 billion tons of intercity freight originated within the above 17 states and the District of Columbia during 1970 (35). Since this figure represents over 45 percent of the nation's entire intercity domestic tonnage for that year, the need for an efficient, well-coordinated transportation network in the Region cannot be overemphasized.

Within the Region, rail, motor, and water carriers, in addition to pipelines, compete for the intercity shipment of various commodities and products. Figure 1 indicates the manner in which intercity freight tonnage originating in this section of the United States was divided among the different modes in 1970 while Figure 2 on page 5 depicts how the modal shares are altered when ton-miles, rather than tonnage, is used to measure freight movement. The difference between the two figures can be attributed to the fact that the average rail haul is longer than the average haul made by truck (35). When revenue received from shipping is used as a base for comparing different modes, trucking becomes the leading mode in the Region as shown by Figure 3 on page 6 . In 1970 trucks originated over 63 percent of the freight revenue in the Northeast and Midwest, representing about 15.5 billion dollars (35). Railroads were able to generate only 27 percent of the total revenue, trailed by water carriers with 4 percent, air freight service involving 3.5 percent, and pipelines with only 2.5 percent (35).

Several factors may be cited as being responsible for the decline in railroad patronage which has occurred in the Northeast and Midwest over the past thirty years. The first factor involves the age of both the railroad plant and the manufacturing companies located within the Region. Because this area was the first part of

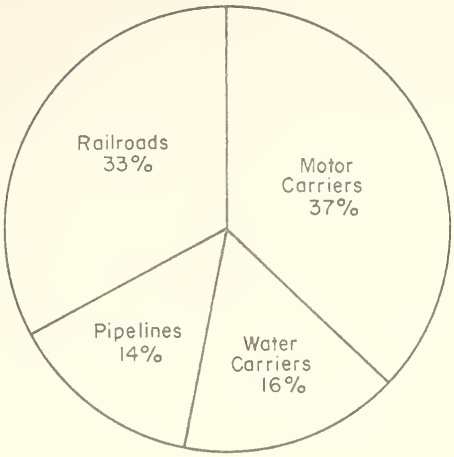


FIGURE 1. MODAL SPLIT OF INTERCITY FREIGHT TONNAGE ORIGINATING IN THE NORTHEAST AND MIDWEST REGION - 1970. SOURCE: USRA (35, P.138)

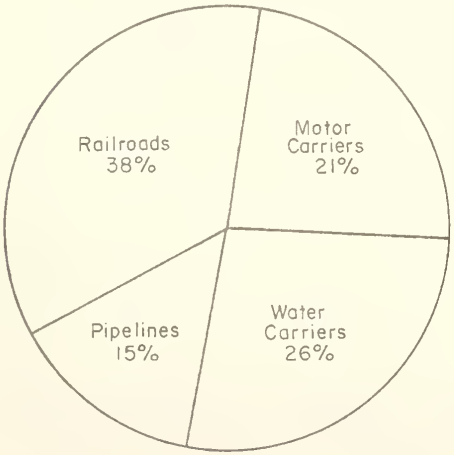


FIGURE 2. MODAL SPLIT OF INTERCITY FREIGHT TON-MILES ORIGINATING IN THE NORTHEAST AND MIDWEST REGION - 1970. SOURCE: USRA (35, P.138)

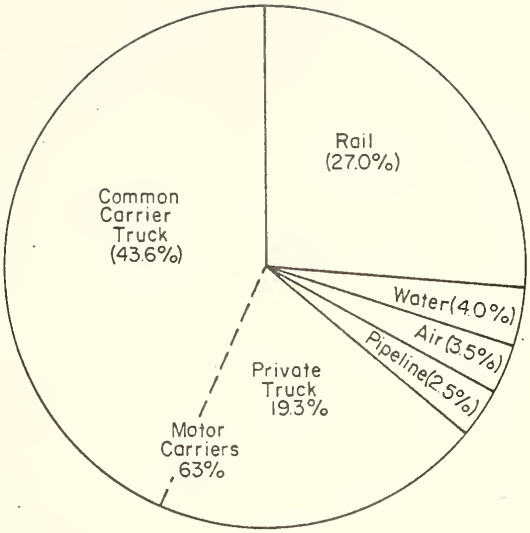


FIGURE 3. ORIGINATED FREIGHT REVENUES IN THE REGION BY MODE - 1970. SOURCE: U.S.R.A. (35, P. 139)

the nation to be developed, it is characterized by aging rail facilities and manufacturing concerns. The trackage and stations predominating in the Region were built during the early stages of railroad construction and were intended originally for local service use, as opposed to the demands of heavy-duty, intercity transportation. The present railroad system in the Northeast and Midwest consists of the splicing of hundreds of constituent rail lines with each possessing its own outdated branches and spurs (35).

Other reasons for waning railroad utilization in the Region include the slow growth rate of the area's industries, the depletion of natural resources in some parts of the Northeast, and the increasing tendency of the Region's companies to manufacture goods possessing a suitability to shipping by truck. In particular, natural resource depletion has forced industries to move to newer, expanding population centers, generally in the South or in the West. In essence, the problems faced by rail carriers in the Northeast and Midwest are simply extensions of problems found in other sections of the country, intensified by the aging nature of the Region's rail network plus the prevalence of older, slower-growing industries which require less rail service.

In the years from 1970 to 1973, the difficulties besetting the Region's railroads culminated in the bankruptcies of 8 carriers in the Northeast and Midwest. The Penn Central Transportation Company, the nation's largest transportation company with over 90,000 employees, was one of the rail carriers unable to reorganize for the resumption of solvent operations. This company is responsible for approximately 20 percent of all freight cars loaded in the United States, and over 70 percent of the company's traffic interchanges with other railroads (35). More importantly,

the 8 bankrupt rail carriers employ more than 120,000 persons, which represents one-fourth of all U. S. rail employees (35).

As mentioned previously, the U. S. Congress responded to the rash of bankruptcies by preparing a railroad restructuring legislative action tailored specifically to the needs of the financially-troubled rail carriers in the Region. A concise discussion of the major points found in the Regional Rail Reorganization Act of 1973 is included as the next part of this chapter.

The Federal Response to the Region's Railroad Dilemma

The Regional Rail Reorganization Act of 1973 shortened the normal bankruptcy process confronting a fiscally-troubled rail carrier by granting special powers and responsibilities to the following agencies: United States Railway Association (USRA or the Association), Rail Services Planning Office (RSPO or the Office) of the Interstate Commerce Commission, United States Department of Transportation (DOT), and the Special Court. The Act's purpose, according to the U. S. Congress, is to promote "the identification of a rail service system in the northeast and midwest region which is adequate to meet the needs and service requirements of this region and of the national rail transportation system" (23).

Two of the aforementioned agencies, USRA and RSPO, were important creations authorized by the Act. The first group USRA was given the responsibility of planning the reorganization of the Region's railroad system. The organization possesses the power to abandon rail lines; it may also issue obligations, offer loans to rail carriers, and provide financial assistance to states for track acquisition or modernization (7).

Empowered by the Act primarily to oversee the Association's work in order to ensure that the Act's statutory goals are being followed, the second agency RSPO is also charged with conducting public hearings on the major reports mandated by the Act. A third principal duty of RSPO is to determine the amount of governmental subsidy required for those lines proposed for exclusion from the restructured rail network. The Act also authorized the establishment of a third agency created solely for operating the reorganized rail system in the Region. This operating entity, to be headquartered in Philadelphia, Pennsylvania, is known as the Consolidated Rail Corporation (ConRail). The three groups listed above are the primary agencies having responsibility for the final system's planning, design, and operation.

The Act mandated the issuance of two major reports prior to submission of the Final System Plan to the U. S. Congress in July 1975. The initial report, prepared by the U. S. Department of Transportation (DOT Report), was released exactly thirty days from the law's enactment, as required by provisions of the Act itself (33). Concerned not only with bankrupt rail carriers but also with solvent transportation companies, the DOT Report classified approximately 25 percent of the Region's trackage as being "potentially excess". The status of Indiana's rail lines was even worse than that existing for the Region as a whole since DOT regarded 37 percent of the State's 6,405 miles of trackage as being unneeded. Not surprisingly, the DOT Report was strongly challenged by the individual states within the Region. The states disagreed with DOT's concept of massive railroad abandonment as a solution to the economic woes of the area's carriers.

On February 26, 1975, USRA issued the second report required by the provisions of the 1973 Act. This report contained the Preliminary System Plan for restructuring the Region's system of railroads (35). Dealing exclusively with the rail lines owned by the bankrupt carriers, the Association concluded that nearly 6,200 miles of trackage within the Northeast and Midwest should be omitted from the ConRail network. The Association's recommendation of extensive branch line abandonment drew critical public response similar to that received by the DOT Report. The opinion shared by both the public and RSPO was that USRA's line analysis methodology appeared so arbitrary, and the data seemed so thoroughly inadequate, as to render incorrect a majority of the light-density line decisions (17).

The Final System Plan was submitted to the U. S. Congress for its approval on July 26, 1975 (36). According to USRA, the Final System Plan considers all the information received since publication of the Preliminary System Plan and provides a more detailed resolution of the principal issues involved in reorganizing the Region's rail network. Excluded from the Final System Plan are about 6,900 miles of railway, of which about 5,750 miles are currently in service and 1,150 miles are out of service (36). Approximately 1,393 miles of roadway within Indiana are omitted from the ConRail network. However, service on these lines in Indiana may be maintained under the Act's service continuation subsidy program.

Beginning with the issuance of the DOT Report (33) and continuing until the submission of the Final System Plan (36) to Congress for its approval, each of the affected states has shown considerable interest in the disposition of the rail reorganization matter. Following passage of the Act in 1973, the seventeen

states located in the Region began to realize the need for obtaining information on how branch line abandonment might affect either statewide transportation planning or economic development. The succeeding section provides a general discussion of the manner in which states may become involved in the rail reorganization process. A description of Indiana's railroad planning program, including this State's response to the rail service discontinuance issue, is also discussed briefly.

The States' Response to the Region's Railroad Dilemma

Following release of the DOT Report (33), the seventeen states and the District of Columbia became dramatically aware of a need for their input into any discussions related to the fate of the railroads located in the Northeast and Midwest. Each prepared comprehensive replies to federal proposals for railroad reorganization. Moreover, the states within the Region formed an organization named the Conference of States on Regional Rail Reorganization (CSRRR) for the purpose of permitting interaction and cooperation between rail planning agencies in various states.

The Act authorizes the establishing of a unique role for individual states through the administration of a rail service continuation subsidy program which provides financial assistance to rail lines excluded from the ConRail system. As discussed in the Final System Plan (36), the subsidy program has a planned length of two years with the federal government allocating ninety million dollars to the program each year. An important requirement which a state must meet in order to receive service continuation subsidies involves the development of a comprehensive State Rail

Plan. Furthermore, the Plan must be administered by an agency staffed by personnel who are capable of conducting an ongoing program of research and development.

Currently, in Indiana, the Governor's Rail Task Force is the agency responsible for directing this State's rail planning efforts. From February 1974 to March 1975, the Task Force prepared four reports relating the agency's ideas on the disposition of individual light-density USRA rail segments within Indiana. Each of the reports was submitted to USRA for the purpose of providing input into the planning process (10).

As shown in the preceding paragraph, Indiana, through the actions of its Governor's Rail Task Force, has become involved in rail reorganization procedures. This involvement is important since the need for both state and local governments to be aware of current rail issues cannot be overemphasized. Throughout this country's history, the primary state role in the federalist governmental system has consisted of being a cooperative, knowledgeable partner to the federal government, and it is essential that this type of relationship also prevail in the area of railroad reorganization (9). John W. Fuller expresses why a state-federal working partnership is essential in rail planning when he writes:

> "Perhaps the most compelling reason for states to play a part in rail reorganization and abandonment matters, however, is that trade-offs involving explicit government support for the several modes are most commonly made at the state or metropolitan level. As state powers and funding increase, the project-level decision will frequently arise as to whether subsidy should be given a rail operation or capital investments be undertaken on a parallel highway." (9).

RAIL FREIGHT DIVERSION AND THE HIGHWAY SYSTEM

As discussed previously in the first chapter, the rail industry has suffered a decline in its share of the intercity freight market during the past thirty years. Within this same period, the trucking industry has made tremendous gains, coinciding with the development of the Interstate Highway System. The railroad abandonment issue has added to concern over the capability and condition of the national highway system, or more specifically, the rural road system. Shifts in transportation demand, such as might result from rail service discontinuance, would likely increase truck shipments on rural roads. The question thus arises: If the rural rail network is reduced, are local highway facilities capable of accommodating the increased number of heavy vehicles? Larger loads and a greater number of truck passes might result in further deterioration of rural highway segments which already possess major deficiencies. This chapter investigates the truck-rail competitive arena, and it also discusses the public costs associated with rail traffic diversion and the highway system.

Rail-Truck Competition for Freight Transportation

Over the last thirty years, there has been a trend toward shippers and manufacturing firms transporting more commodities by motor carrier and less products by the railroad. What are the major reasons underlying trucking's gains in intercity freight transportation?

Trucking has become an increasingly important segment of the United States transportation industry. Total truck registrations increased from 13 million in 1963 to nearly 20 million in 1972, and total truck mileage rose approximately 40 percent between 1967 and 1972 (29). Trucking's growth, occurring primarily at the railroads' expense, has resulted from the industry's matching, and in some cases, undercutting rail freight rates over a wide variety of commodities while providing shippers with far better service than they received from the railroads (38). Regarded as possessing greater versatility and offering a higher level of service than the rail industry, trucking's advantages of flexibility and service quality appear to decrease with length of haul.

In their article, "Competition Between Rail and Truck in Intercity Freight Transportation", D. W. Woods and T. A. Domencich list five major advantages that trucks offer to shippers utilizing the mode: 1) smaller shipment sizes, 2) reduced time in transit, 3) more dependable delivery times, 4) superior equipment availability, and 5) less damage to freight while it is in transit (38). Two additional advantages of trucks which deserve to be mentioned include the relatively low capital requirements of the industry when compared to other modes and the mode's flexibility which eliminates double handling of commodities.

Besides the above advantages inherent to the trucking mode itself, basic changes in underlying market conditions which tend to favor the mode have also occurred during recent years. The first of these changes is related to the shift in production locations presently occurring in the United States. Multiple centers of industrial and natural resource development enable companies to move their plants from older,

established areas thereby creating fewer interdependent regions within the nation. Shifts in manufacturing plant locations have been particularly numerous in the Northeast and Midwest as industries have departed for the southern and western sections of the nation. At the present, the proximity of good highways is becoming a prime factor in business or plant situation; thus, trucks, along with airplanes, are able to acquire the largest share of the transportation market associated with decentralized shippers desiring high-quality service (35).

A second factor related to both market conditions and freight modal demand involves the active growth experienced by those industrial sectors which have little need for rail transportation. Although freight transportation in general has grown slowly in relation to the gross national product, the segment of the freight market experiencing augmentation is less suitable for rail service and more adaptable to trucking (35). The fastest growth has occurred in the manufacturing sectors producing goods, such as computers or entertainment equipment, which are not only highly valuable relative to their bulk but also distinctly vulnerable to the "crashing" technology of the railroads.

The railroad industry is not at a complete disadvantage to its freight transportation counterpart, and the mode's advantages should also be discussed. Railroad transportation is more efficient for long-distance shipments and is better suited for large movements of bulk commodities, namely, grain, fertilizer, or coal. Potash, phosphates, anhydrous ammonia, and propane gas arriving at agribusinesses from faraway suppliers are generally regarded as being transported more readily, more efficiently, and more cheaply via the railroad. Rail lines which are serving

coal fields are essential to the large-scale movement of this resource, and the possibility of a future massive conversion to coal as an energy source could cause increased rail freight tonnages and ton-miles. Furthermore, certain impediments to highway freight transportation, such as local road and bridge conditions or frost laws which limit truck weights during winter months, do exist in some states.

In addition to the above viewpoints, it appears that the need for railroad abandonment decisions may be as much a result of technological change in railroad operations as it is of intermodal competition (28). Although truck competition has taken high-rated traffic from the railroads in most rural areas, new innovations such as containerization, intermodalism, carpooling, and unit trains seem to represent possibilities for railroads retaining their share of the future intercity freight market. Thus, railroad technological changes, such as the ones listed above, can be expected to remove more and more local branch lines from service with an accompanying increase in traffic on rural highway facilities.

Public Costs Related to Rail Traffic Diversion and the Highway System

Freight diversion resulting from rail service discontinuance implies that an affected region's economy and transportation network will likely be altered. The local farmer, livestock processor, and manufacturing company must seek an alternative mode for transporting their commodities to the market. Shipping goods by motor carrier is often the sole available alternative. A major potential cost to a region confronted with losing rail service to areal

businesses and agricultural interests involves the damage to local roads and streets arising from increased numbers of heavily-loaded commercial vehicles. Several views pertaining to what effects increased truck traffic can have on local highways are discussed in the succeeding paragraphs.

According to Woods and Domencich, an increase in heavy commercial traffic volumes could affect public costs of highway construction and maintenance in at least four specific ways:

1. By increasing the total volume of vehicle traffic and the accompanying increase in the required capacity of the road.
2. By escalating maintenance expenditures.
3. By shortening the effective life span of a facility.
4. By raising the design standards required for a facility of a given capacity - particularly with regard to pavement and road base thickness (38).

Truck traffic contributes its share, along with other vehicles, to road wear and damage which forces maintenance expenditures and the eventual strengthening of a highway's pavement structure. The effect of passenger vehicles on road wear in proportion to the effect of single and multiple unit trucks is small. Moreover, the impact of multiple unit trucks on a pavement structure is generally eight or nine times greater than the impact of single units (8). Thus, large, heavy commercial vehicles are responsible for virtually all road wear. Although both usage and the passage of time create highway deterioration, road tests conducted by the American Association of State Highway Officials (now known as the American Association of State Highway and Transportation Officials, AASHTO) have shown wear

due to traffic to be far more destructive than time (38). Increasing the number of trucks using a highway facility would essentially shorten the life of the roadway pavement forced to accommodate additional load repetitions.

The accommodation of heavier, more frequent commercial vehicles becomes a serious safety problem when the affected rural bridges are either structurally deficient or physically obsolescent. Additional loads due to the abandoning of a nearby rail line serve to aggravate existing deficiencies of narrow, aging structures and to hasten the need for their replacement or repair. Thus, the manner in which increased traffic intensifies the physical deterioration of rural highway structures that are already deficient is worthy of investigation.

With regard to its impact upon highway capacity requirements, a heavy truck is equivalent to more than a single passenger vehicle. According to the Highway Capacity Manual, the average dual-tired vehicle, when traveling on level terrain or downgrades, is equivalent in a capacity sense to two passenger cars on multilane highways and to between two and three automobiles on two-lane highways, depending on the road's level of service (11). In rolling terrain, the equivalency factors for two-lane and multilane facilities increase to five and four automobiles, respectively; within mountainous terrain the equivalencies become even greater - ten vehicles for two-lane roadways and eight passenger cars for multilane facilities (11). These facts raise the question as to whether an increased number of trucks might reduce the effective capacity of a facility, particularly a two-lane roadway, to the point where the quality of service provided to all highway users declines.

The issue of increased truck traffic arising from branch line abandonment must be placed in perspective to the largely two-lane primary and secondary highway network of the United States. Although highways located in rural areas have undergone limited improvement within recent years, over three-fifths of all arterial and collector roads were cited by the States in 1970 as being deficient, based upon factors such as traffic capacity, alignment, roadway width, pavement condition, and drainage characteristics (29). Most of this deficient mileage, excluding local roads, was on the collector road system. Minor collectors accounted for nearly one-half of the deficient mileage while more than one-fourth of the inadequate mileage involved major collectors. The collector system is an important part of the nation's entire highway network since it accommodates primarily intracounty and other short-distance trips. Because rural collectors serve mainly to connect agricultural areas to nearby large trade centers, this functional classification would be the highways most likely to assume diverted rail traffic.

The load-bearing ability of highways is a major indicator of their capacity to withstand heavy-load transportation demands. Of the 2.4 million miles of surfaced rural roads within the United States in 1972, 0.5 million, or 21 percent, were regarded as possessing a high load-bearing ability (29). In Indiana, this percentage is even less since only 12.2 percent of the total miles of rural roads were rated in 1972 as capable of accommodating heavy loads.

A second consideration in appraising road capability involves changes in the size of loads moving over highways. The average load on main rural roads, an important classification in State highway systems, increased by over 70 percent from 1960 to 1970 (29).

Furthermore, the frequency of loads weighing 40,000 pounds or more increased by nearly 90 percent during the same 10 years (29). This increased loading signifies a growth of demand on our nation's road system - a situation which could lead to surface and structural deterioration unless load-bearing ability has kept pace.

Besides the aforementioned problems associated with rural highway deficiencies, the number of inadequate bridges situated on rural roads also pose a serious restriction to the continuing flow of traffic along these routes (29). The Office of Highway Planning, located within the U. S. Department of Transportation, estimated in 1972 that there were approximately 200,000 bridges on arterial and collector roads which are anticipated to remain rural through 1990 (32). Since over two-thirds of these structures were found on rural collectors, a highway classification containing many miles of deficient roadway, it appears likely that a problem with deficient bridges also exists. In the state of Indiana, the State Highway System had 39 bridges of less than 16 feet in width as of 1972. The Indiana Highway System, other than State roads, included 7,871 bridges with less than 16 feet of width as of the same year (27). Furthermore, a special study conducted in 1975 by the Purdue University Highway Extension and Research Project for Indiana Counties (HERPIC) revealed more than 9,585 Indiana county bridges to be unsatisfactory (21). Thus, since the number of trucks which travel over rural structures each year will likely increase after railroad abandonment, the situation concerning deficient bridges is particularly worrisome.

PURPOSE OF THE STUDY

The basic purpose of this study was the development of a methodology which can be used to estimate the impact of railroad abandonment on rural highways and bridges. The evaluative procedure can be employed by railroad shipper groups, local governments, and state agencies for assessing the costs of upgrading the rural highway system in order to accommodate increased numbers of heavily-loaded commercial vehicles. The methodology presented in this report for estimating abandonment's effects on local highways and bridges was based in large part on the pavement design procedures which have been developed by the American Association of State Highway Officials. In addition, graphs which can be employed for the direct determination of railroad abandonment's highway impact were prepared in order to facilitate the utilization of the adopted methodology.

To demonstrate how the evaluative methodology is to be used, two areas within Indiana that are confronted with the possible loss of railroad service were selected as case studies. The case studies presented in this report were included as working examples of the adopted procedure. As a means of determining what business alternatives are available to rail users threatened with the loss of direct railroad accessibility, thirty-three shippers located in the two case study areas were personally visited and interviewed. The results of the completed rail user survey were felt to be informative since the opinions expressed by these railroad patrons may be indicative of the opinions of shippers in other areas who are confronted with a similar abandonment dilemma.

PART TWO

PRINCIPLES AND PROCEDURES

RESEARCH METHODOLOGY

The Original Specifications

The original plan of this research effort involved the determination of railroad abandonment's impact on the highway network for each area within Indiana in danger of losing access to rail transportation. According to the United States Railway Association's Final System Plan of July 26, 1975 (36), 1,393 miles of active, light-density railroad trackage in the State were to be excluded from the ConRail network. This trackage, which is eligible for state or local subsidization under the provisions of the Regional Rail Reorganization Act of 1973, constitutes this study's subject of analysis.

For each rail line under abandonment consideration, the acquisition of two separate sets of information was felt to be necessary. The first set consists of information related to the magnitude and type of rail shipments which were made on a railroad facility during a particular year. Data within the set include such items as the number of carloads originating or terminating along a rail branch line, the type of commodities being transported in the rail cars, and the rail car tonnages for each commodity moved on the facility. The second data set encompasses the determination of certain characteristics of those rural highways and bridges forced to accommodate heavier, more frequent truck passes as a result of railroad abandonment. Such highway statistics as the average daily traffic and the percentage of motor carriers using a specific road facility had to be ascertained

before this project's analysis could be performed.

In the initial phase of the research effort, however, it was felt that the development of a procedure for evaluating the highway impact associated with rail service discontinuance would be more relevant than the conducting of a broad, macroscopic assessment of railroad abandonment's effect on Indiana's highways. This procedure can be used by both local groups of rail users or state and local government agencies as a way of assessing abandonment's highway impact. The general principles and procedures are applicable to any region. As a means of demonstrating use of existing data sources in addition to use of the procedure itself, two areas within Indiana confronted with possible railroad service elimination were chosen to provide a realistic explanation of the methodology. The two rail segments selected for procedural demonstrations include: 1) the portion of USRA Line Number 429 from Decatur, Indiana to Portland, Indiana and 2) USRA Line Numbers 589 and 590 situated between the cities of North Vernon, Indiana and Madison, Indiana. Each of these rail lines was recommended for inclusion in the final ConRail system by the Governor's Rail Task Force, but to no avail. Furthermore, Lieutenant Governor Robert Orr listed the North Vernon to Madison segment as one of six Indiana rail facilities excluded from ConRail which must retain service (20). A complete description of the two areas, including highway, railroad, and bridge characteristics, can be found in Chapter 10 in Part III.

The Revised Approach

The basic premise underlying the methodology developed by this project may be stated as follows: Any increase in the number or weight of motor carriers

using a highway facility arising from rail service discontinuance will create a need for additional asphaltic concrete overlays on the highways forced to assume additional truck passes. The need for resurfacing existing highways in order to accommodate heavier, more frequent truck loads represents a cost which must be borne by either state or local governments. By deferring necessary repaving and maintenance, the road's service life will be reduced, and an accompanying decline in pavement rideability and serviceability will also occur. Thus, by examining the interaction between increases in motor carrier traffic and the amount of added bituminous concrete overlay required to handle the traffic increases, it becomes possible to delineate those levels of rail activity at which abandonment's impact is particularly acute, and the types of highways which appear more susceptible to abandonment's effects.

With the American Association of State Highway Officials (AASHO) Interim Guide for Design of Pavement Structures (3) serving as the theoretical basis, a procedure was developed which can be used to indicate how much additional bituminous concrete overlay is required to accommodate an increase in the number of 18-kip equivalent axle loads being assumed by a highway. The procedure is particularly adaptable to the state of Indiana although it can be easily used for any case in which its basic data requirements have been met. The third chapter of Part II provides a complete explanation of the assumptions and equations on which the procedure was founded.

To reduce the amount of work associated with an agency's using the adopted methodology, graphs were prepared that show directly the amount of added asphaltic concrete required for handling increases in truck volumes or weights which may occur on a highway.

The graphs were prepared for the specific case of a 4 percent annual growth in traffic volumes; this percentage increase represents normal traffic growth unrelated to railroad abandonment. Furthermore, the impact graphs utilize a ten-year analysis period beginning at the time of railroad abandonment. It must be emphasized that the graphs represent only a simplification of the impact procedure, with the 4 percent annual traffic growth rate being chosen because it has been noted in various volume studies conducted by the Indiana State Highway Commission. The methodology itself, exclusive of the graphs, can be used with various rates of traffic growth and any length of analysis period. Chapter 7 describes the impact graphs in detail.

In addition to the evaluative approach developed by this research effort for measuring the highway pavement impact of rail service discontinuance, a procedure was also created for estimating abandonment's effects on local bridges. Narrow, aging bridges pose a serious safety problem since signs of fatigue indicate the nearing of the end of a structure's service life. With increasing numbers of heavy commercial vehicles using these antiquated bridges, the need for replacing or strengthening the affected bridges will occur sooner than originally planned. The method presented in Chapter 8 for ascertaining the adequacy of affected bridges to accommodate heavier, more frequent loads is suggested by this research effort as one approach for estimating railroad abandonment's effects on highway structures.

The two procedures discussed above - the process for evaluating railroad abandonment's impact on highway pavements and the approach for estimating its effects on local bridges - represent two major components of

the methodology introduced by this research project. The evaluative methodology not only contains the above procedures but also encompasses methods to accomplish the following: 1) the determination of basic input data required by the adopted procedures, and 2) the assessment of pavement resurfacing costs attributed to traffic increases arising from rail service discontinuance. The evaluative methodology represents the culmination of this project's developmental efforts. The final chapter of Part II contains a description of the various procedures constituting the developed evaluative system.

BASIC CONSIDERATIONS IN THE DESIGN OF HIGHWAY PAVEMENTS

Introduction

The design of highway pavements encompasses a study of soils and paving materials, their behavior under load, and the design of a structure to transport that load under various climatic conditions. The major functions of a pavement structure are twofold: 1) the distribution of wheel loads to the subgrade soil in such a manner that no part of the pavement or subgrade is overstressed, and 2) the provision of a smooth, continuous wearing surface which is well-drained and which will continue to provide a foundation for transitory loads.

All pavements fall in one of two broad categories: flexible pavements and rigid pavements. The flexible pavement consists of a relatively thin wearing surface constructed over a base and subbase courses, with all three layers resting upon a compacted subgrade. On the other hand, rigid pavements are composed of Portland cement concrete, and these pavements may be constructed either with or without a base course between the pavement and the subgrade. A third category of pavement structures consists of overlay pavements. An overlay may be defined as a thickness of rigid or nonrigid pavement constructed on the base pavement in order to increase its load-carrying capacity (39). Pavement overlays may be composed of either bituminous concrete, Portland cement concrete, or base courses plus a paving material, and they can be placed over either rigid or flexible pavements as a strengthening measure.

The primary difference between the two pavement types is the manner in which the load is distributed over the subgrade. The rigid pavement, possessing a high modulus of elasticity and considerable rigidity, tends to distribute the load over a relatively wide area of soil. These two characteristics cause a major part of the structural capacity to be supplied by the slab itself. Conversely, the load-carrying capacity of flexible pavements is a result of the load-distributing characteristics of the layered system. The strength of a flexible pavement comes from the accumulation of thick layers and the associated distribution of load over the subgrade, as opposed to a rigid pavement's bending action of the concrete slab. Most notably, the design thickness of a flexible pavement is influenced considerably by the strength of the subgrade.

Until 1940 most design of flexible or rigid pavements was performed based upon either experience or rule-of-thumb procedures. However, beginning in the 1950's, the gear loads imposed by heavy aircraft created the need for a more rational approach. During this period, the Corps of Engineers was responsible for directing much research toward the development of rational pavement design methods. Beginning in the 1960's, the American Association of State Highway Officials (AASHO) and the Bureau of Public Roads (now designated the Federal Highway Administration) began concentrated efforts to evaluate existing pavement design procedures and to formulate new procedures based upon relatively large-scale experimental road tests (22). The results of these field test programs have been a major influence on current pavement design concepts. In addition, the monitoring of the performance of prototype pavements in service has influenced design principles significantly. Nevertheless, because the

formulation of reasonable pavement design procedures has been fairly recent, many misconceptions related to pavement design still exist today.

The purpose of this chapter is to explain briefly several of the basic considerations in pavement design as a means of familiarizing the reader with some of its principal concepts. This presentation of background information should facilitate the understanding of the highway impact evaluative procedure as it is discussed in Chapter 6.

Traffic Loads

Pavement loads are those caused by transient wheel loads of vehicles possessing a wide range of axle configurations and weight distributions. The general performance equations developed at the 1962 AASHO Road Test consist of single-axle load equations that describe pavement behavior as it is subjected to repeated applications of an axle load of any one type and weight. In order to obtain information on the behavior of pavements acted upon by mixed traffic - normal highway traffic consisting of both single and tandem axles of a variety of weights, it becomes necessary to establish a basic or standard wheel load. At the present, all pavement designs require converting traffic flows by various vehicle types to equivalent 18,000-pound single-axle load applications. This 18-kip single-axle load application is not simply a unit of weight. The measurement may be regarded as a standardized unit of vehicle "use" of the roadway resource; it is the standardized amount of roadway damage caused by passing a single axle transporting 18,000 pounds over the roadway surface (19). Using this concept as a base, it becomes possible for a tandem axle to carry 32,000 pounds without

surpassing the equivalent 18,000-pound single-axle wheel load. Although maximum axle loads for highways vary from state to state, the majority of states have established 18,000 pounds as the maximum single-axle load and 32,000 pounds as the upper tandem-axle load.

The solution of the problem posed by converting single and tandem axles of different weights to equivalent 18-kip single-axle load repetitions involved the development of equivalency factors which reduce given single or tandem axles of known weights to equivalent 18-kip single-axle load applications. These equivalency factors were developed from the AASHO Road Test, and they have been tabulated in the AASHO Interim Guide for the Design of Pavement Structures (3).

Application of the equivalent wheel load concept is necessary since actual traffic loads include various wheel and axle configurations while design techniques are based strictly on single-axle wheel load repetitions.

Flexible Pavement Design

There are several methods currently being used within this country for the design of flexible pavements. These methods include the AASHO, the Kentucky Highway Department, TAI (The Asphalt Institute), the NSCA (National Crushed Stone Association), and the California methods of design. Because the development of this study's methodology was based upon the design procedures recommended by the American Association of State Highway Officials, the AASHO design method for flexible pavements is the sole method discussed within this section.

The AASHO flexible pavement design procedure is based on the results of the AASHO Road Test which occurred at Ottawa, Illinois during the late 1950's and early 1960's. Upon completion of the field tests, the

AASHO Committee on Design presented an Interim Design Guide (1) in 1961 and published a revised edition during 1972 following extensive review and research of the original version.

The final flexible pavement design equation presented in the 1972 version of the AASHO Interim Guide for Design of Pavement Structures (3) is as follows:

$$\log EAL = 9.36 \log (SN+1) - 0.20 + \frac{\log \left[(4.2-p_t)/(4.2-1.5)\right]}{0.40+\left[1094/(SN+1)^{5.19}\right]} + \log \frac{1}{R} + 0.372(S-3.0)$$

As shown above, this final design expression relates the number of 18-kip single-axle load applications (EAL) needed to attain a predetermined terminal serviceability level (p_t) for any given pavement structure (SN), climatic condition (R), and subgrade soil (S) (39). As a means of simplifying the application of this design expression, the equation has been converted to nomographic form in the AASHO Interim Guide for Design of Pavement Structures (3) for various terminal serviceability levels.

The five variables utilized in the flexible pavement design equation may be defined in the following manner:

1. Terminal serviceability (p_t). This parameter is an empirical value used as a measure of a pavement's performance. The p_t value may be regarded as the lowest serviceability that will be tolerated on a highway at the end of a traffic analysis period before resurfacing or reconstruction is necessary. A value of 2.5 is assigned to major highways with a p_t of 2.0 being recommended for lower volume roads.

2. Equivalent 18-kip single-axle load applications (EAL). The total number of 18-kip load repetitions which can be assumed by a particular highway during the traffic analysis period must be determined. Because the equivalency factors used for converting mixed traffic to the standard design wheel load are also a function of the structural number, a structural number has to be assumed for initial conversion. Generally, a structural number of 3.0 is used for this purpose. By using this value, an overestimation of EAL occurs, but the resulting error is insignificant in most cases.
3. Regional factor (R). This parameter's purpose is to make the design expression applicable for design of pavements in areas with climatic characteristics different from those prevalent at the Road Test site. A generalized contour map for the United States has been derived which indicates different R-values for different sections in the country. Nevertheless, the limitations of such a map are obvious, and a better means of selecting the correct R-value is through the use of an experienced engineer's judgment combined with an analysis of local highway conditions.
4. Soil support value (S). This variable is included in the equation as a means of making the design procedure applicable to roadbed soils other than the soil type occurring at the Road Test site. Since this value cannot be directly acquired through testing, it becomes necessary to establish some type of correlation between standard soil tests and the S-parameter. The selection of the proper soil support value demands sound engineering judgment.

5. Structural Number (SN). "The SN is defined as an index number derived from an analysis of traffic, roadbed soil conditions, and a regional factor that may be converted to thickness of various flexible pavement layers through the use of suitable layer coefficients related to the type of material being used in each layer of the pavement structure" (37).

The layer coefficient (specified as a_1, a_2, and a_3 for surface, base, and subbase, respectively) is the empirical relationship between a pavement's structural number and the layer thickness. The layer coefficient expresses the relative ability of a material to function as a structural component of the pavement. The SN for the entire pavement is represented by the general equation:

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

where the D_i values are the respective layer thicknesses.

Rigid Pavement Design

The AASHO rigid pavement design procedure was used in the development of this project's methodology for evaluating the impact of railroad abandonment on rigid pavements. This AASHO design method is also based on the results of the Road Test conducted at Ottawa, Illinois in the early 1960's. As was the case of the flexible pavement procedure, the rigid pavement design process was introduced in the 1961 Interim Design Guide (2) and presented again in the 1972 revised edition.

To account for conditions other than those which were prevalent at the Road Test site, the rigid pavement design expression was modified using a combination of experience and theory. After incorporating these modifications based primarily on the Spangler equation, the final design expression assumes the form:

$$\log EAL = 7.35 \log(D+1) - 0.06 + \frac{\log\left[(4.5-p_t)/(4.5-1.5)\right]}{1 + \left[1.624\times10^{7}/(D+1)^{8.46}\right]} + (4.22-0.32p_t)\left[\log\left(\frac{f_t}{690}\right)\left(\frac{D^{0.75}-1.132}{D^{0.75}-0.407k^{0.25}}\right)\right]$$

This expression relates the number of 18,000-pound wheel load repetitions (EAL) required to obtain a predefined terminal serviceability level (p_t) for any given slab thickness (D), modulus of subgrade reaction (k), and working stress in concrete (f_t). In the same manner as the flexible design equation, the above expression has been converted to the form of design charts which are presented in the AASHO Interim Guide for Design of Pavement Structures (3) for ease of application.

Five variables are included in the rigid pavement design equation. Terminal serviceability is used in the same manner as it was defined previously for flexible pavements. The dependent variable, the total equivalent 18-kip single-axle load applications, is also defined in a similar fashion to the flexible pavement definition. The only difference is that the concrete slab thickness, rather than the structural number, has to be assumed for the initial conversion of mixed traffic to standard design wheel load applications. This need for an initial assumption again arises because the equivalency factors are a function of the rigid pavement slab thickness.

The other three variables in the rigid pavement design equation are defined as follows:

1. Modulus of subgrade reaction (k). As a way of making the design procedure pertinent to other roadbed soils, a scale for the modulus of subgrade reaction was created by AASHO to represent the range of soils which would be encountered at other sites. The rigid equation utilizes Westergaard's modulus of subgrade reaction, and this parameter represents the load in pounds per square inch on a loaded area of the subgrade or subbase divided by the deflection in inches (3). The k-value may be determined by using previous experience or by correlation with other tests.
2. Working stress in concrete (f_t). The average flexural strength for the concrete at the Road Test was approximately 690 pounds per square inch (psi) at the end of 28 days. AASHO has developed a scale in order to make the rigid pavement design procedure relevant to other concrete flexural strengths. The working stress in concrete is the variable incorporated into this AASHO scale. The working stress is equal to 0.75 times the modulus of rupture of concrete (S_c). The modulus of rupture is defined as the 28-day flexural strength as determined by AASHO Designation T-97 using third-point loading (4). The reason for using the working stress rather than the modulus of rupture involves the incorporation of a factor of safety into the design equation. The smaller f_t-value results in a thicker concrete slab being used for the rigid pavement structure.

3. Rigid pavement slab thickness (D). This variable is simply the thickness in inches of the portland cement concrete slab of a rigid pavement.

Overlay Design Principles

An overlay is placed above an in-service pavement in order to improve its structural strength, its riding quality, its skid resistance, or a combination of any of the above. Several procedures are currently being used for strengthening pavement structures, and these include the Oklahoma, California, and the United States Corps of Engineers methods. Because this research effort was based upon the Corps of Engineers' procedure, this method is the one discussed in the following paragraphs.

The Corps of Engineers has been responsible for developing design methods for rigid and flexible overlays placed above both pavement types. Since most Indiana highways are composed of either flexible overlays above flexible pavements or flexible overlays on rigid pavements, these two design methods are discussed in detail.

The design procedure for flexible overlays on flexible pavements is relatively simple since the process is essentially the same as the regular design procedure for any flexible pavement. The difference between the required thickness and the existing thickness constitutes the amount of bituminous concrete overlay which is needed.

The procedure of flexible overlays placed above rigid pavements is based upon an empirical formula that assigns a structural equivalency to relate the thickness of bituminous concrete and portland cement concrete (3). This expression is of the following form:

$$t = 2.5(Fh_d - h)$$

in which: t = thickness of the overlay, inches.
F = a factor which is a function of the subbase or subgrade.
h_d = the exact design thickness computed from the regular rigid pavement design procedures, inches.
h = the existing pavement thickness, inches.

An important step in this design procedure involves choosing the proper F-value, a function of both the subgrade modulus of support and the type of loading anticipated. The Corps of Engineers' manual, "Engineering and Design, Rigid Airfield Pavements" (26), offers guidance in selecting the proper value of F for general traffic loading conditions.

Summary

The objective of this chapter has been to introduce some of the more important concepts related to pavement design. An understanding of this basic information will facilitate the comprehension of the manner in which the methodology developed by this study actually operates. The succeeding chapters discuss the methodology's application and the data requirements of this study's procedure.

THE ADOPTED PROCEDURE

Using the pavement design concepts discussed in the preceding chapter as a base, this research project developed a procedure to be used for evaluating the impact of railroad abandonment on a highway facility. The procedure is adaptable to the variety of conditions which are encountered when working with highway pavements. The steps involved in the adopted procedure's development are discussed in the following sections.

Assumptions

It is essential that the user of the procedure described within this chapter fully understand the assumptions underlying its development. Briefly stated, these assumptions are as follows:

1. This study assumes that the economic impact of rail service discontinuance on a highway facility, excluding bridges, consists of the cost of resurfacing the facility in order to accommodate the increased number of heavy vehicles traveling the highway. The necessity of overlaying a highway to maintain a predetermined serviceability level incurs an expense which must be borne by either state or local government. By using this report's procedure, a local or state governmental agency can evaluate railroad abandonment's impact in terms of the additional amount of asphaltic concrete overlay needed to prevent either a decline in pavement serviceability or a reduction in the length of the pavement's service life.

2. Since the adopted procedure deals strictly with the incremental impact arising from increased truck traffic due to service elimination along a nearby rail facility, it does not directly consider the present condition of the pavement structure. A knowledge of the current composition of a highway's pavement structure becomes unnecessary when considering that any costs incurred from correcting present deficiencies should be excluded from the economic analysis related to railroad abandonment's impact on local highways. Conversely, implementation of service discontinuance on railroad branch lines can alter the setting of priorities associated with the upgrading and routine maintenance of the rural road system. A rural highway forced to assume additional trucks that are transporting commodities previously moved by way of the railroad might have to be repaved sooner than had been specified in a state's or county's highway maintenance program. Thus, the present condition of a highway's pavement structure must be considered through an analysis of the manner in which a study section's need for upgrading is escalated by the effects of railroad abandonment.
3. Because the AASHO equations for the design of flexible and rigid pavements were employed as the basis for the development of the adopted methodology, the assumptions underlying each of the design equations, as presented in the AASHO Interim Guide for Design of Pavement Structures (3), are also applicable to the procedure generated by this research effort.

Development of the Procedure

This section discusses the steps taken in developing the procedure to be used for evaluating railroad abandonment's impact on nearby highway facilities. Because increased numbers of heavily-loaded vehicles generally create a need for strengthening the pavement structure, the measure most likely used for this strengthening process involves placing a bituminous concrete overlay above the existing highway pavement. Since the existing pavement may be classified as either a rigid pavement or a flexible pavement, the procedure, as described in the following paragraphs, is pertinent to two separate conditions: 1) flexible overlays on rigid pavements, and 2) flexible overlays on flexible pavements.

Flexible Overlays on Rigid Pavements

In evaluating the impact of rail service discontinuance on rigid highway pavements, this research effort utilized two well-known pavement design expressions: 1) the AASHO rigid pavement design equation, and 2) the U. S. Corps of Engineers' overlay design formula. Since each of the equations was described in a previous chapter, this section discusses the application of the expressions to the problem of evaluating the effect of truck traffic increases on a highway.

By using a modified form of the Corps of Engineers' design procedure for flexible overlays on rigid pavements, calculations of the additional amount of asphaltic concrete required to accommodate various increases in the number of equivalent 18-kip single-axle load applications (EAL) can be performed. The modified overlay design expression assumes the following form:

$$\Delta t = 2.5(FD_A - D_{NA})$$

in which: Δt = the increase in required overlay thickness resulting from railroad abandonment, inches.

F = a factor related to the condition of the existing pavement.

D_A = the exact design thickness, as determined from the AASHO rigid pavement design procedures, following EAL increases due to railroad abandonment, inches.

D_{NA} = the exact design thickness, as determined from the AASHO rigid pavement design procedures, under conditions of normal traffic growth and no railroad abandonment, inches.

In order for a user agency to compute the required amount of additional asphaltic concrete overlay, the AASHO rigid pavement design equation must be utilized twice. In the first case, an EAL value for the section undergoing analysis must be determined for conditions of normal traffic growth and no rail service discontinuance. This step includes the selection of an appropriate analysis period, such as ten or twenty years, to be used for evaluating abandonment's highway impact. By using this EAL value in conjunction with either the AASHO rigid pavement design equation or the AASHO design nomographs, reproduced as Figures 29 and 30 in Appendix A, the appropriate concrete slab thickness (D_{NA}) can be ascertained.

In the second case, the EAL value to be calculated includes the additional load applications resulting from over-the-road transportation of goods previously moved via the railroad. This latter EAL value is

determined for the same length of analysis period as the former, and it is also used in conjunction with either the AASHO rigid pavement design equation or design nomographs in order to obtain a second concrete slab thickness (D_A). However, it is necessary to modify this value of D_A by a factor F which is related to the condition of the existing pavement. The inclusion of the F-value in the expression for flexible overlays on rigid pavements permits some consideration to be given to a study section's present pavement condition. Through the substitution of this modified value of D_A along with the previously computed value of D_{NA} into the procedure's design formula, the parameter Δt can be determined.

A major step of the adopted methodology involves the determination of the proper EAL values. Within the United States, several methods are currently being used for the computation of the number of equivalent 18-kip single-axle load applications which have been, or will be, assumed by a highway pavement. The method used by this research effort for ascertaining needed EAL values is described extensively in Chapter 8. In addition, the approach adopted by this project for the conversion of truckloads of diverted freight commodities into corresponding EAL values is discussed in a later chapter of this report.

Flexible Overlays on Flexible Pavements

In measuring railroad abandonment's impact on flexible highway pavements, this research effort utilized the AASHO flexible pavement design procedure. The AASHO expression was discussed in a previous chapter; therefore, this section's aim is to describe the manner in which the equation was used in the adopted procedure.

Based upon AASHO flexible pavement design techniques - the methods pertinent to the case of flexible overlays on flexible pavements, calculations of the amount of additional bituminous concrete overlay can be performed for various EAL increases which could arise from rail service discontinuance. Because present deficiencies in a study section's pavement structure should not be directly considered in an economic analysis related to railroad abandonment's highway impact, the expression to be used for determining the thickness increases assumes the following form:

$$\Delta t = \frac{SN_A - SN_{NA}}{a_1}$$

where: Δt = the increase in required overlay thickness as a direct result of railroad abandonment, inches.

SN_A = the exact design structural number, as determined from the AASHO design procedures, following EAL increases due to railroad abandonment.

SN_{NA} = the exact design structural number, as determined from the AASHO design procedures, under conditions of normal traffic growth and no railroad abandonment.

a_1 = the layer coefficient related to the type of material being used for the surface layer of the pavement structure.

Similar to the case of flexible overlays over rigid pavements, a user of the adopted procedure must employ the AASHO flexible pavement design equation twice in order to ascertain the necessary thickness of bituminous concrete overlay which should be placed

above the original flexible pavement. For the first case, which corresponds to no rail service discontinuance, the calculated EAL value represents normal growth of traffic volumes. This step involves the selection of an appropriate analysis period for measuring the possible impact of a rail line's closing on local highways. This EAL value used along with either the AASHO flexible pavement design equation or the AASHO design nomographs, included in this report as Figures 27 and 28 of Appendix A, enables a user agency to calculate the appropriate structural number (SN_{NA}).

In the second case, the EAL value requiring computation takes into account the added load repetitions caused by increased numbers of trucks carrying freight formerly moved by way of the railroad. This latter EAL value is determined for the same length of analysis period as the former, and it is also used along with either the AASHO flexible pavement design expression or the AASHO design nomographs to yield a second design structural number (SN_A).

The difference in the two aforementioned structural numbers, divided by an appropriate layer coefficient (a_1), equals the added amount of bituminous concrete overlay (Δt) which can be attributed to railroad abandonment. The proper layer coefficient is related to the type of material employed as the pavement's surface layer. Since this parameter's value can vary, it is suggested that user agencies consult their state highway department as a means of obtaining an estimate of a_1.

Summary Comments Pertaining to the Adopted Procedure

The procedure adopted by this research effort includes two formulas to be used for ascertaining the impact of rail service discontinuance on local highways.

The developed formulas are applicable to two separate conditions; 1) flexible overlays on rigid pavements, and 2) flexible overlays on flexible pavements. To re-emphasize, it is essential that a user of the methodology completely understand the assumptions underlying its development.

A critical step in the chosen procedure consists of the determination of the appropriate concrete slab thickness or the proper design structural number, depending upon the pavement composition of the highway section being studied. The easiest means of accomplishing this step involves employing the AASHO design nomographs that have been included in this report as Appendix A. Nevertheless, in order to prevent user agencies, particularly those outside the field of transportation engineering, from having to employ design nomographs with which they may have had no experience, this research project prepared a series of graphs which can be read directly for the additional amount of required overlay. The following chapter explains how the graphs were prepared and for what cases the graphs are applicable.

THE IMPACT GRAPHS

As a means of simplifying the adopted procedure, this research effort prepared a series of graphs to be used by rail shipper groups or state and local governmental agencies for evaluating the seriousness of an abandoned rail line's highway impact. The primary purpose of this chapter is to explain how the graphs can be utilized and to provide several examples illustrating use of the impact graphs.

Assumptions

The three assumptions stated in the preceding chapter are equally pertinent to the development of the impact graphs since the graphs represent merely a simplifying extension of the adopted procedure itself. Furthermore, two additional assumptions have been made in preparing the graphs with regard to normal traffic growth. These suppositions are as follows:

1. The graphs incorporate a normal increase in the volume of traffic which will be using Indiana's highways in future years. An increase of 4 percent per year was utilized in the graphs' preparation because this traffic growth rate has been noted in various volume studies conducted by the Indiana State Highway Commission (ISHC). This growth in the absolute number of vehicles is not related in any manner to the additional trucks required for transporting freight diverted from the railroads.

2. It was assumed that any percentage increase in traffic volumes will be distributed throughout the various vehicle weight classifications in such a manner that a corresponding percentage increase in the number of equivalent 18-kip single-axle load applications will also occur.

Using the Impact Graphs

This section discusses briefly how the impact graphs were prepared for the two pavement classifications described in the previous chapter: 1) flexible overlays on rigid pavements, and 2) flexible overlays on flexible pavements. More importantly, the following paragraphs explain in detail the procedure to be utilized with each of the two types of graphs and include worked examples to familiarize user agencies with the proper techniques.

Flexible Overlays on Rigid Pavements

The impact graphs pertaining to flexible overlays on rigid pavements were based directly on the formula presented in the foregoing chapter describing the development of the adopted procedure. However, a computer program, rather than the AASHO design nomographs, was employed by this project for determining all concrete slab thicknesses. The computer analysis - based upon an equation stated in NCHRP Report 128, "Evaluation of AASHO Interim Guides for Design of Pavement Structures" (37) - permitted accurate calculations of concrete slab thicknesses to be performed; thus, the program was preferable to rigid pavement design nomographs which require considerable interpolation.

The impact graphs for flexible overlays on rigid pavements were developed for a terminal serviceability level of 2.5. The value of the parameter F was assumed to equal 1.0, a conservative estimate. The length of time chosen for the analysis period is ten years from the date of rail service discontinuance. Normal traffic growth of 4 percent per year, along with its corresponding increase in EAL applications, has been assumed to occur throughout the ten-year time period. In order to make the graphs applicable to as many conditions related to highway pavements as possible, different values of both the modulus of subgrade reaction (k) and the working stress in concrete (f_t) were considered. The k-values employed in the analysis were 100,250, and 500 pounds per square inch per inch (psi/in.) while values of f_t assumed during the graphs' preparation included 350,500, and 700 psi.

As specified on the impact graphs, Figures 4 through 12 for rigid pavements and Figures 13 through 22 for flexible pavements, the EAL value associated with an individual impact curve represents the EAL at the initiation of rail service discontinuance. This value equals the accumulated number of equivalent 18-kip single-axle load repetitions which the pavement has assumed from the time that the highway was first opened to traffic to the time when abandonment of a nearby rail line occurs. However, it is important to note that the graphs have been constructed in a manner which causes the horizontal scale, "Increase in EAL (percent)", to be expressed as a percentage of the future-year EAL. This horizon-year EAL value can be calculated quite simply from the following expression:

$$EAL_H = EAL_I \ (1+r)^n$$

in which: EAL_H = the EAL value of the study section at the end of the analysis period.

EAL_I = the EAL value of the study section at the beginning of the analysis period.

r = the normal annual rate of traffic growth expressed as a decimal fraction.

n = the length of the analysis period, years.

The reason for selecting the larger horizon-year EAL value rather than its initial-year counterpart for the base of comparison involves the need for taking into account the normal rate of traffic growth occurring during the entire analysis period. It was felt that due consideration must be given to this normal increase of EAL applications since this increase occurs independently of rail service discontinuance.

In the discussion which follows, the technique of selecting an impact curve and of estimating the effect of railroad abandonment on a highway pavement by using the graphs is explained for the case of flexible overlays over rigid pavements. The method demands the following input data:

1. Modulus of subgrade reaction (k).
2. Working stress in concrete (f_t).
3. Accumulated equivalent 18-kip single-axle load applications at the time of railroad abandonment (EAL_I).
4. Additional equivalent 18-kip single-axle load repetitions due to over-the-road transportation of goods previously moved via the railroad (EAL_D).

The technique for determining the additional bituminous concrete overlay required to accommodate an increased number of trucks using a highway facility is a simple four-step process:

1. Select the appropriate graph based on the given k and f_t-values.
2. Determine EAL_D, the additional EAL applications resulting from a rail line's closing. This step involves a conversion of rail carloads into an equivalent number of truckloads, followed by a conversion of truckloads into equivalent 18-kip single-axle load repetitions. Yearly increases must be summed over the analysis period in order to obtain the value of EAL_D.
3. Express EAL_D as a percentage by dividing this number by the value of EAL_H, the final-year EAL which has taken into account normal traffic growth:

$$\text{Percent increase in EAL} = \frac{EAL_D}{EAL_H} \%$$

4. Based on the EAL value at the initial year of railroad abandonment and the percent increase in EAL as computed in step 3, determine the increase in required overlay thickness (Δt) from the graph chosen in step 1, as illustrated by the example below.

Example

Given:

- k = 250.0.
- f_t = 500.0.
- EAL_I = 1,000,000.

Solution:

1. Figure 8 should be used for the input values of k and f_t.

2. Assume that the trucks transporting freight previously moved via the railroad create an additional 75,000 EAL applications per year, then:

$$EAL_D = 75,000 \times 10 = 750,000.$$

3. Percent increase in EAL = $\frac{750,000}{1,480,250} = 51\%$.

4. From Figure 8, based on an EAL_I of 1,000,000 and a percent increase in EAL of 51 percent, the increase in bituminous concrete overlay equals 1.38 inches.

In Figures 4 through 12, 9 graphs are presented that can be used to measure the effect of rail service discontinuance on a rigid pavement, expressed in terms of additional thickness of bituminous concrete overlay. As stated previously, 3 k-values, together with 3 values of f_t, were used in the graphs' preparation. The maximum number of curves found on any graph is 7 with fewer being found on those graphs where the effect of EAL variations is not highly significant. The 7 EAL values include $5x10^4$, 10^5, $5x10^5$, 10^6, $5x10^6$, 10^7, and $1.5x10^7$.

Flexible Overlays on Flexible Pavements

The impact graphs for the case of flexible overlays over flexible pavements were founded on the following equation which was discussed in the preceding chapter:

$$\Delta t = \frac{SN_A - SN_{NA}}{a_1}$$

Similar to the approach taken with flexible overlays on rigid pavements, a computer program, as opposed to the

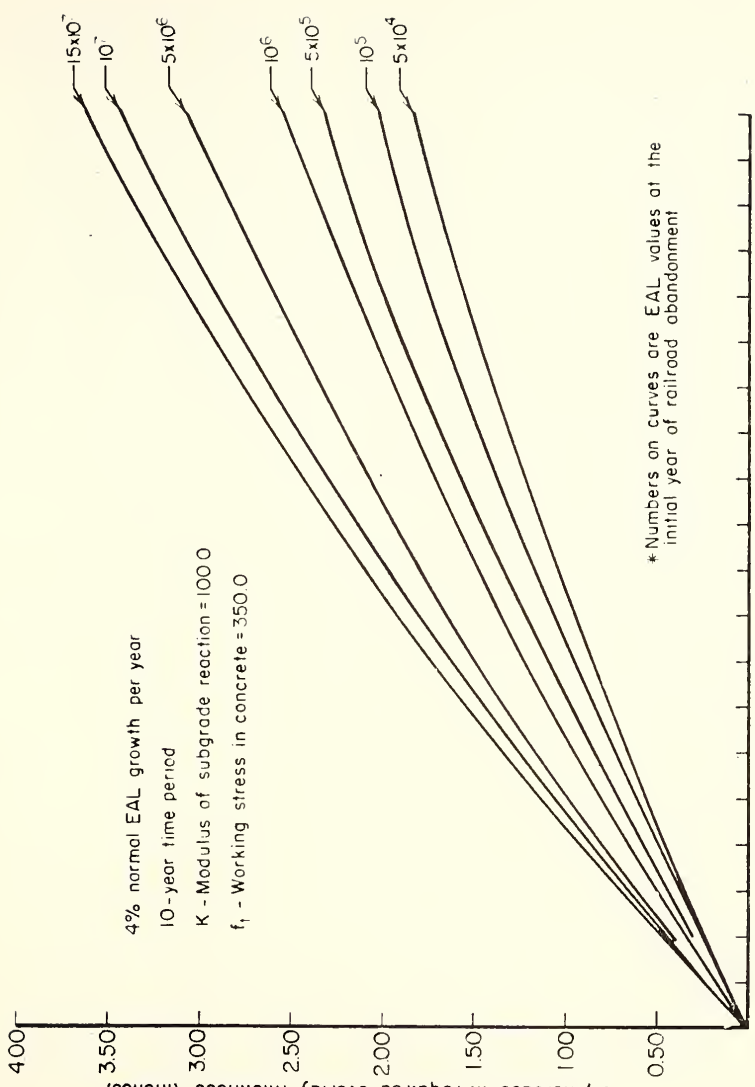

4% normal EAL growth per year
10-year time period
K - Modulus of subgrade reaction = 100.0
f_t - Working stress in concrete = 350.0
Δt, Increase in required overlay thickness (inches)
Increase in EAL (percent)
*Numbers on curves are EAL values at the initial year of railroad abandonment
$15x10^7$
10^7
$5x10^6$
10^6
$5x10^5$
10^5
$5x10^4$

FIGURE 4. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

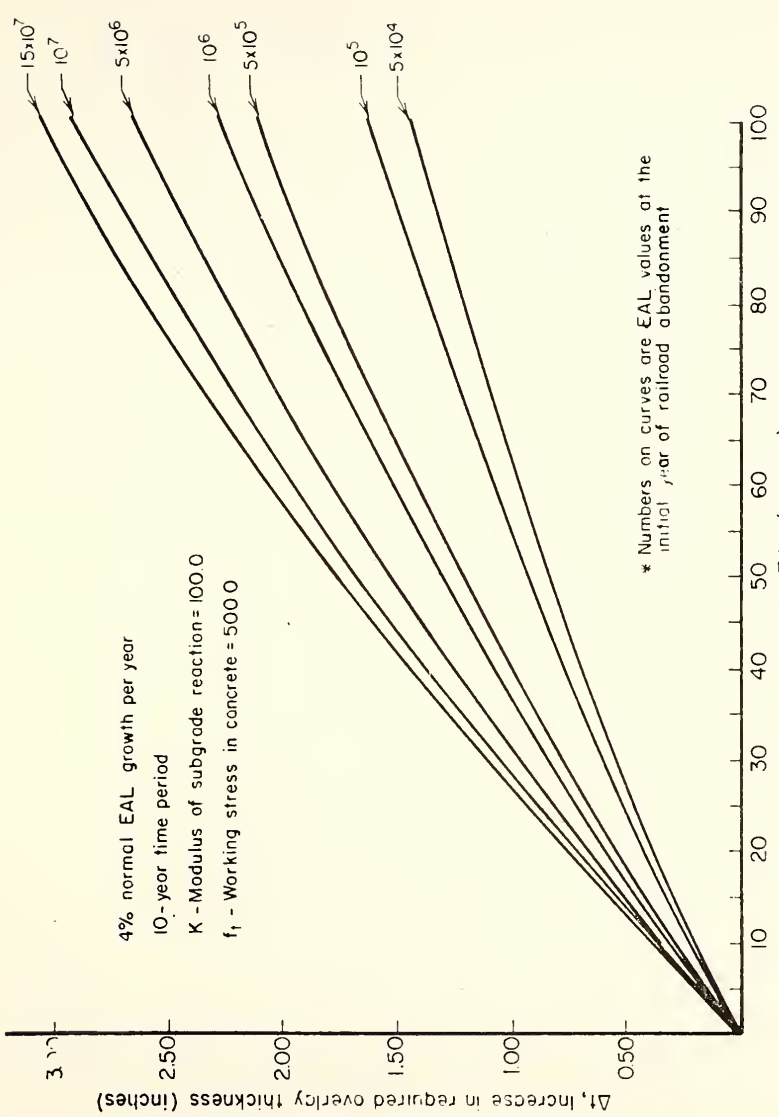


FIGURE 5. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

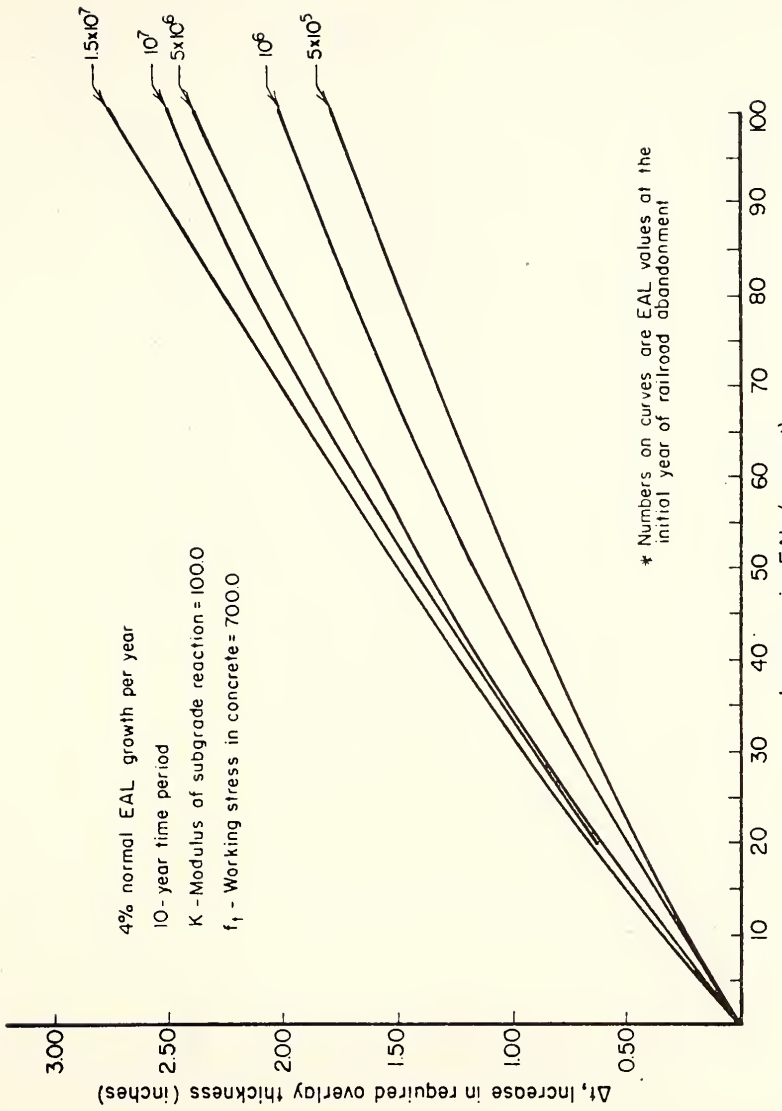


FIGURE 6. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

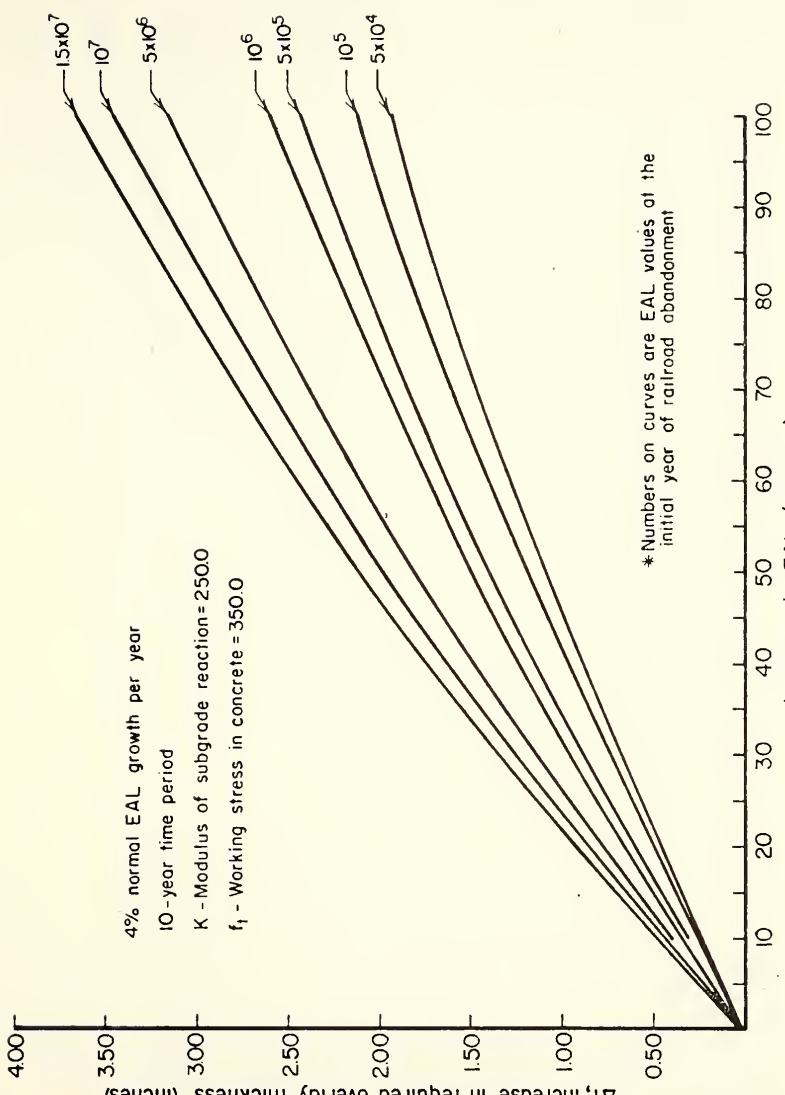


FIGURE 7. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

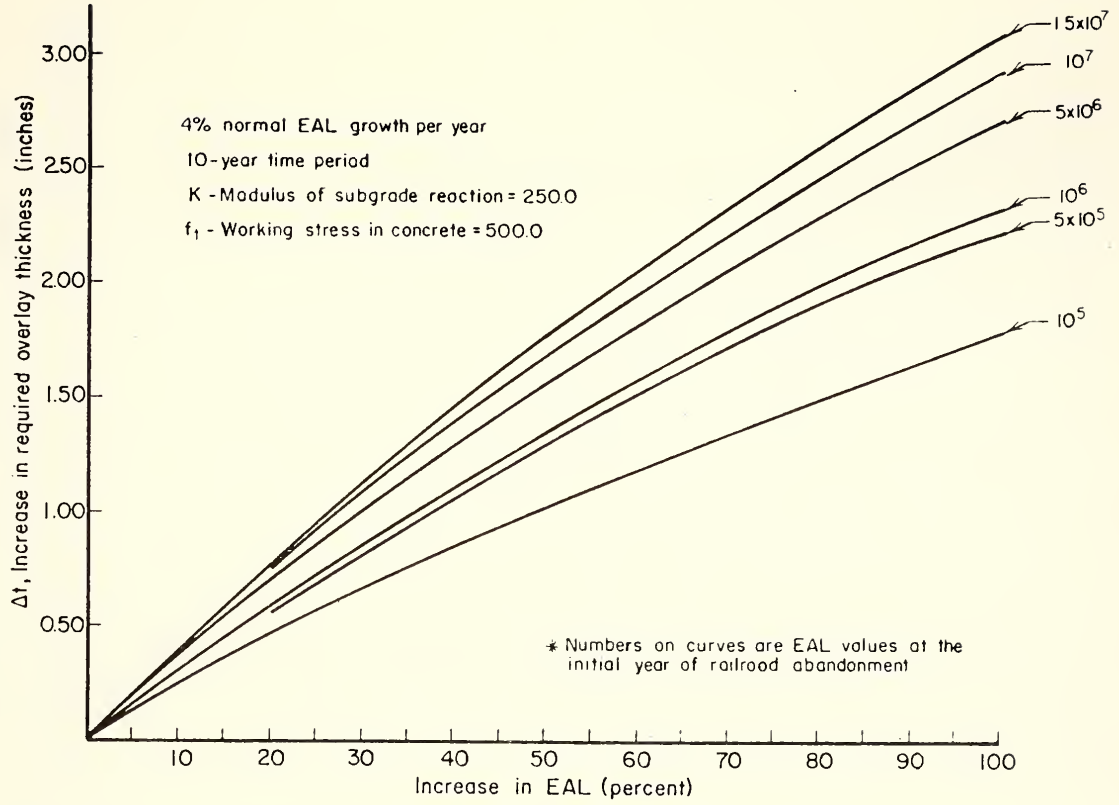


FIGURE 8. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

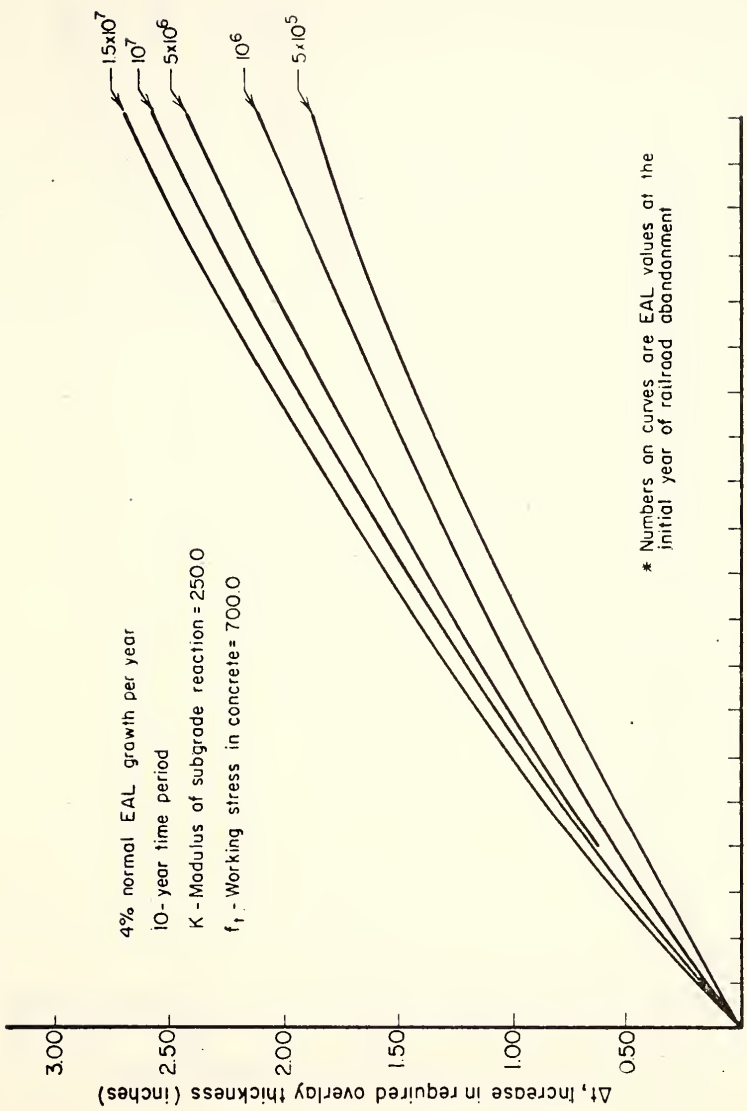


FIGURE 9. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

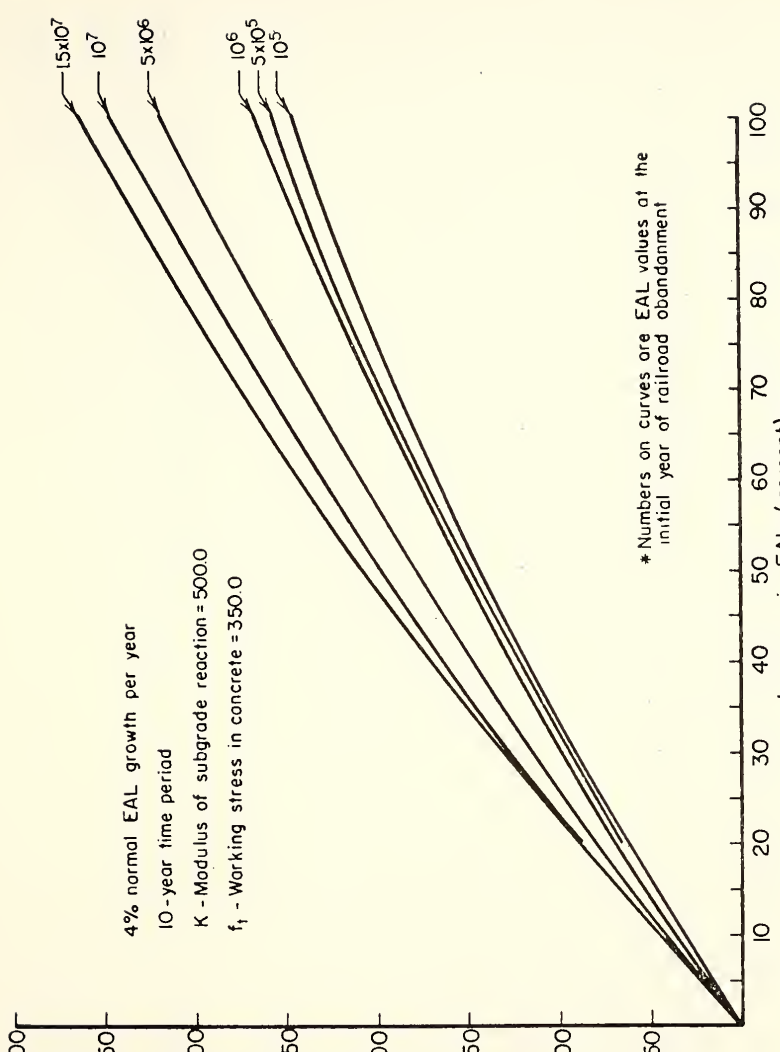


FIGURE 10. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

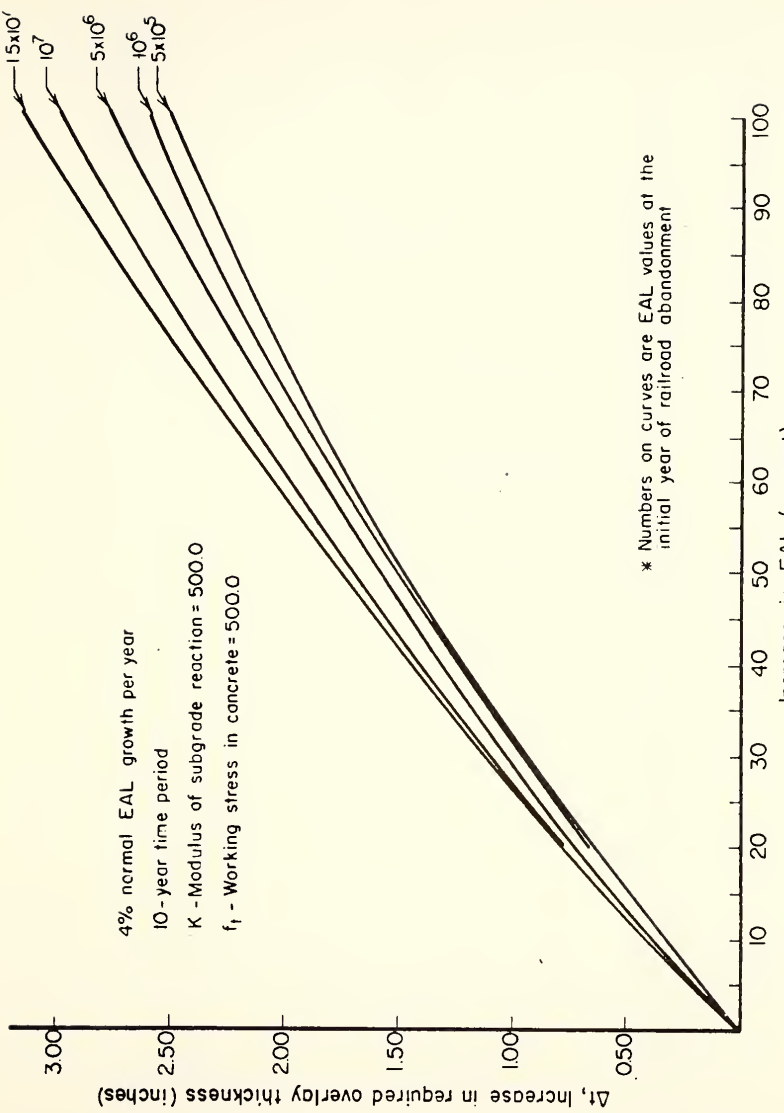


FIGURE 11. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

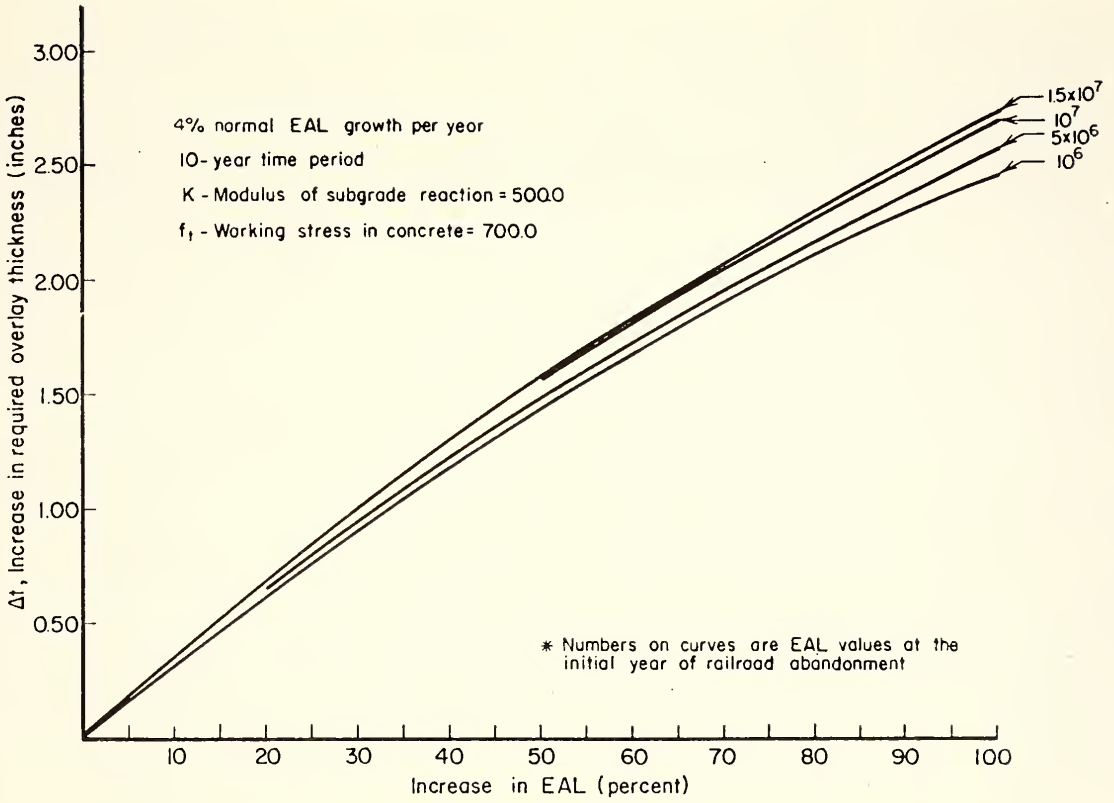


FIGURE 12. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON RIGID PAVEMENTS

AASHO design nomographs, was utilized for determining all design structural numbers. The computer analysis, based on a flexible pavement design equation stated in NCHRP Report 128 (37), allowed fairly exact computations of structural numbers to be performed. As stated previously, the computer program was considered preferable to flexible pavement design nomographs which require much interpolation.

The structural layer coefficient a_1, which represents a pavement surface course composed of a high-stability plant mix, was assumed to equal 0.44 for the development of the graphs. This number was chosen as a suitable layer coefficient value because the coefficient's accuracy had been established from AASHO Road Test data and documented in the AASHO Interim Guide for Design of Pavement Structures (3).

The values of the terminal serviceability level, the length of the period of analysis, and the rate of normal traffic growth are the same for the graphs related to flexible overlays on flexible pavements as they were for the preceding graphs dealing with flexible overlays over rigid pavements. As a means of making the graphs pertinent to a variety of conditions related to flexible pavements, 10 different soil support values covering the entire soil support scale of 1.0 to 10.0 were assumed. The regional factor (R) was assumed to equal 1.0 for each of the 10 soil support values since this value is applicable to a large part of Indiana (37). The parameters, EAL_I and EAL_H, are defined in a similar fashion to their definitions for the previous case of flexible overlays on rigid pavements.

In the discussion which follows, a method of choosing the appropriate impact curve and of measuring the effect of railroad abandonment on a highway facility by using the graphs is described for flexible

overlays over flexible pavements. The method requires the following input data:

1. Soil support value (S).
2. Accumulated equivalent 18-kip single-axle load applications at the time of rail service discontinuance (EAL_I).
3. Additional equivalent 18-kip single-axle load applications due to the trucking of freight previously moved by way of rail transportation (EAL_D).

With the exception of the first step, the technique to be utilized for determining the additional amount of required flexible overlay in the case of flexible pavements is identical to the four-step process explained previously for the rigid pavement classification. However, selection of the appropriate graph is based on the assumed R-value of 1.0 and a given S-value, rather than on the values of k and f_t which had been the preceding case with rigid pavements. The example given below illustrates the four-step technique associated with flexible overlays on flexible pavements.

Example

Given:

- S = 5.0.
- EAL_I = 1,000,000.

Solution:

1. Figure 17 should be utilized for a soil support value of 5.0.
2. Assume the trucks transporting freight previously moved via the railroad create an additional 75,000 EAL applications per year, then:

$$EAL_D = 75{,}000 \times 10 = 750{,}000.$$

3. Percent increase in EAL = $\frac{750,000}{1,480,250}$ = 51%

4. From Figure 17, based on an EAL_I of 1,000,000 and a percent increase in EAL of 51 percent, the increase in bituminous concrete overlay equals 0.48 inches.

In Figures 13 through 22, 10 graphs are presented that can be employed for measuring the impact of railroad abandonment on a flexible pavement, expressed in terms of added thickness of bituminous concrete overlay. Soil support values ranging from 1.0 to 10.0, together with a R-value of 1.0, were used in the impact graphs' preparation. The maximum number of impact curves found on any graph is 7 with fewer being found on those graphs in which the effect of EAL variations is not highly significant. The 7 EAL values incorporated into the graphs are $5x10^4$, 10^5, $5x10^5$, 10^6, $5x10^6$, 10^7, and $1.5x10^7$.

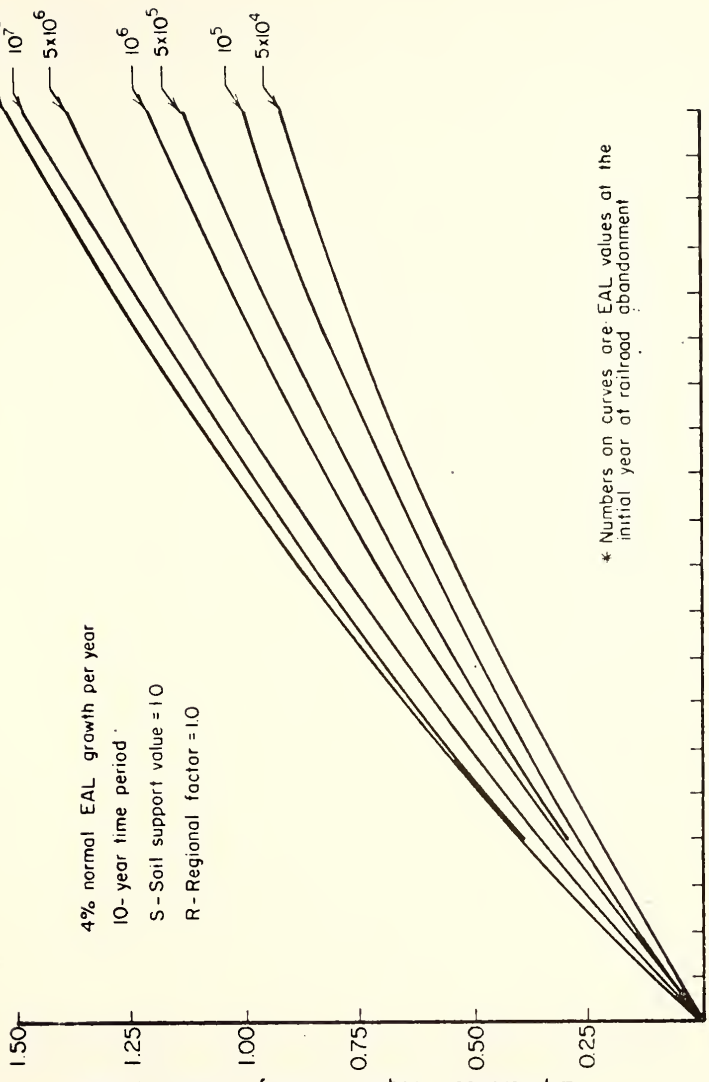


FIGURE 13. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

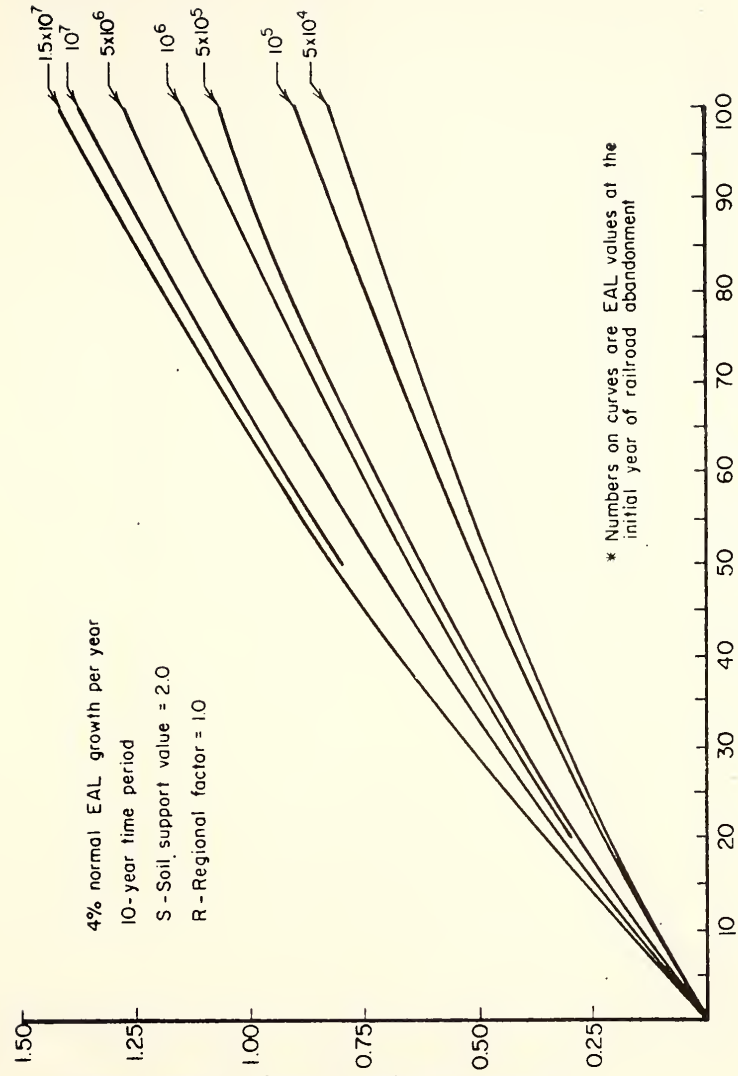


FIGURE 14. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

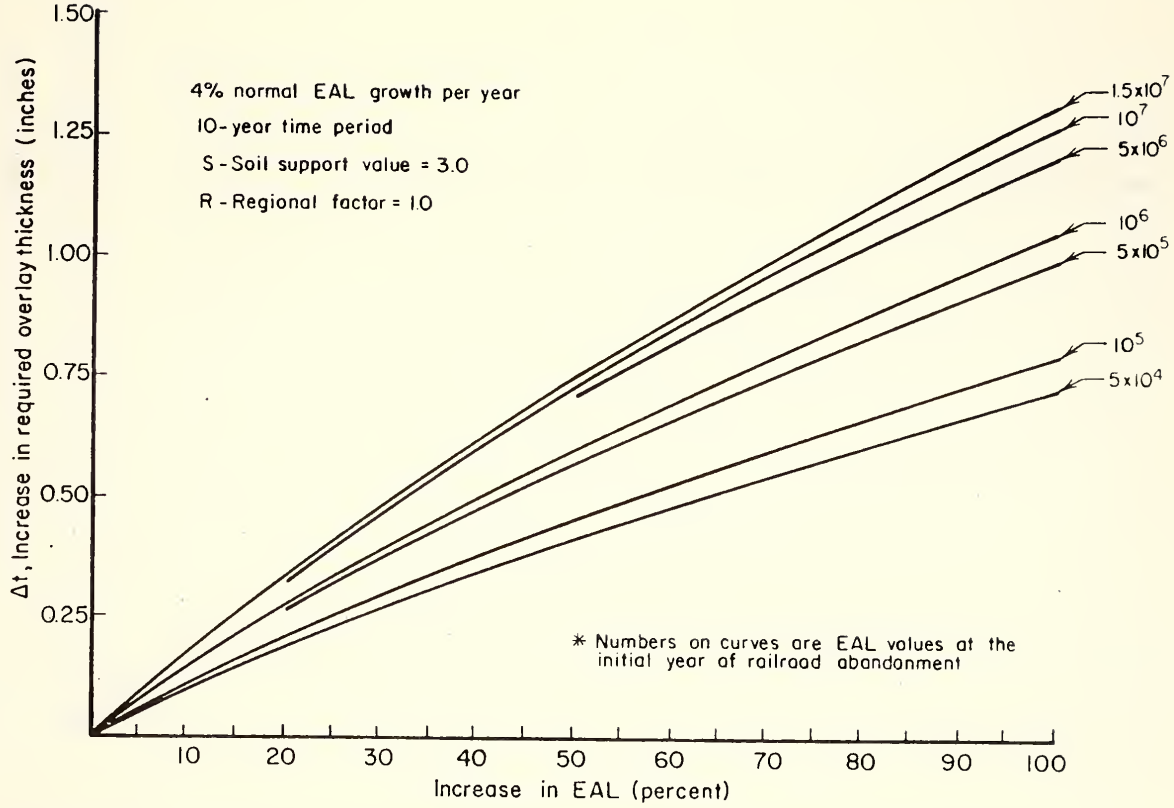


FIGURE 15. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

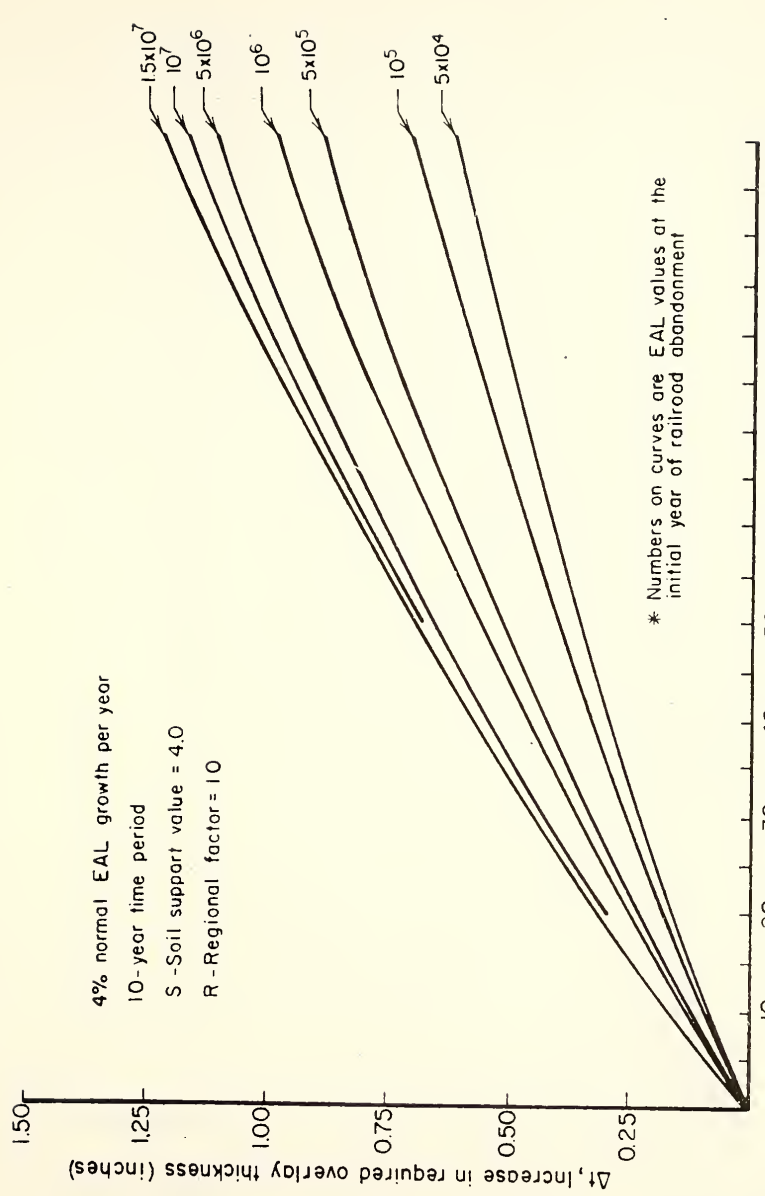


FIGURE 16. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

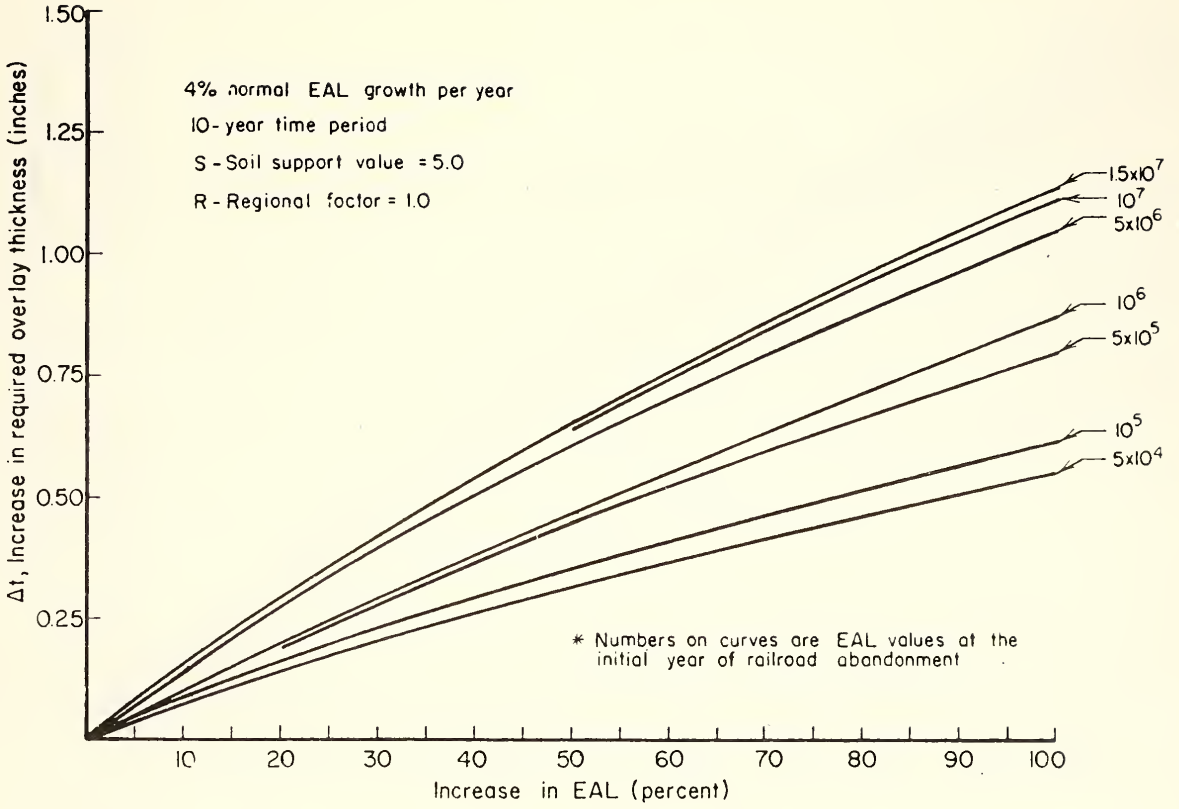


FIGURE 17. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

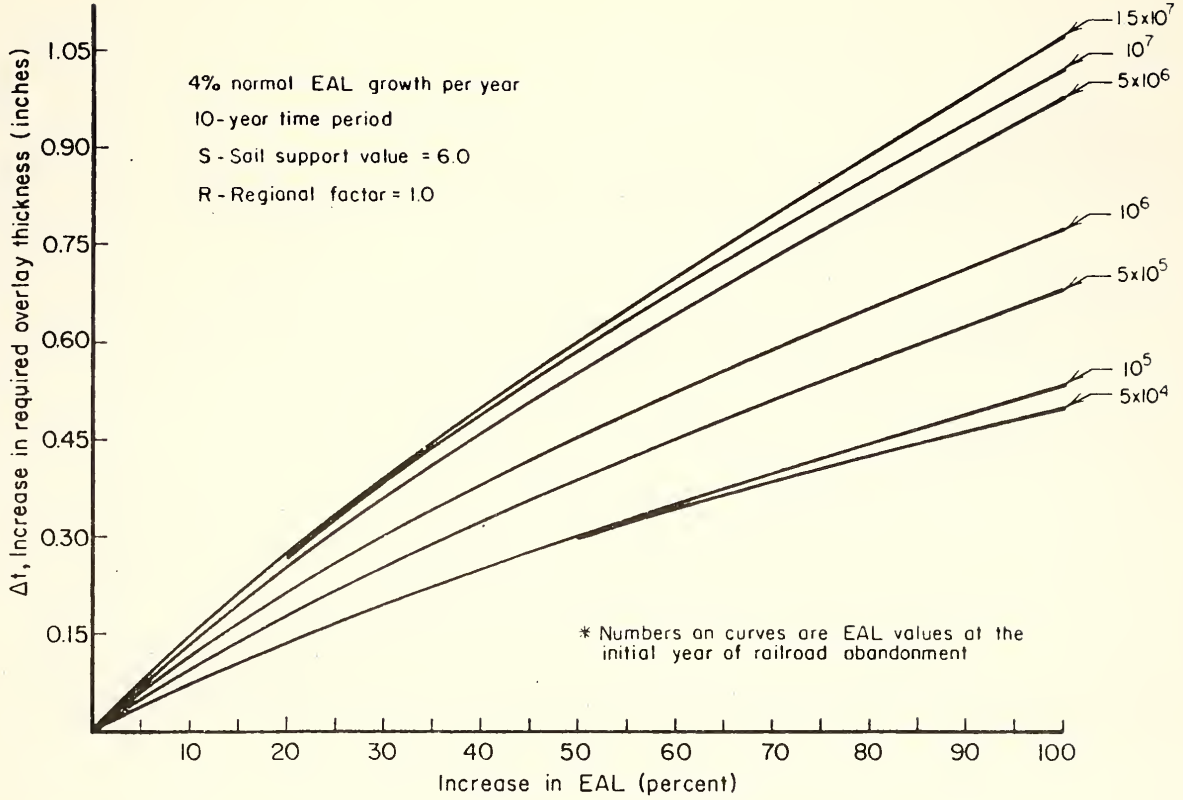


FIGURE 18. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

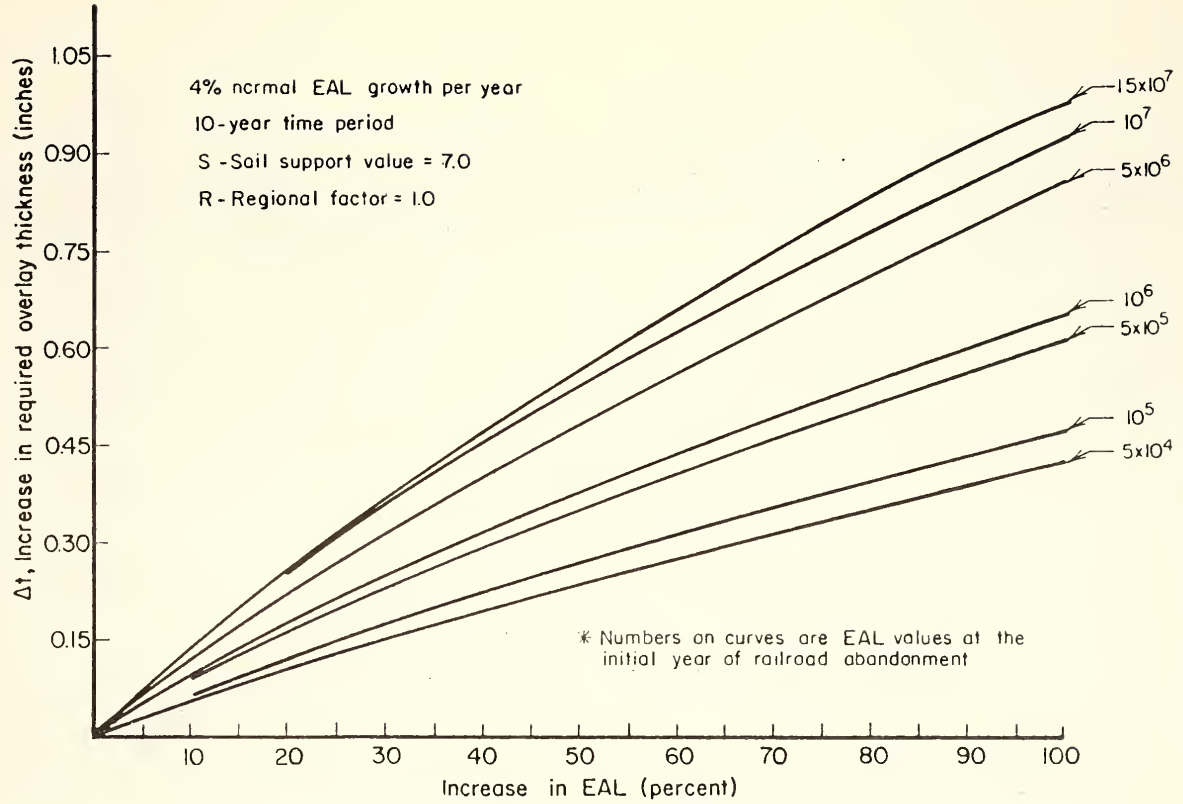


FIGURE 19. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

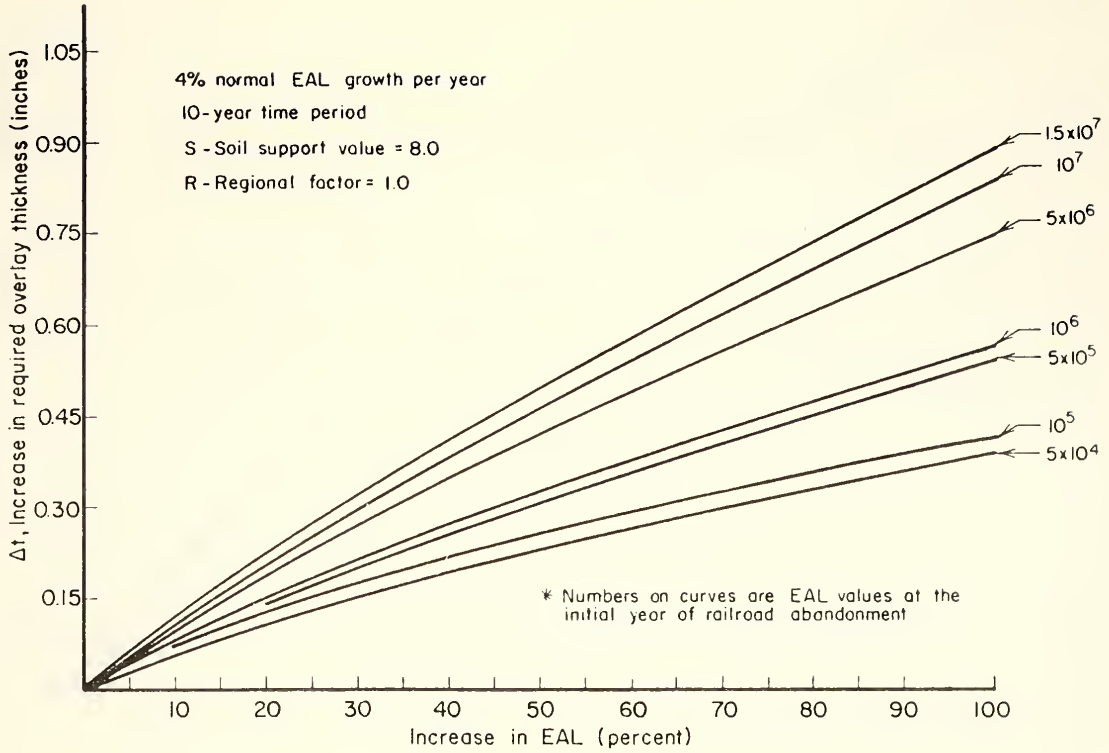


FIGURE 20. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS : FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

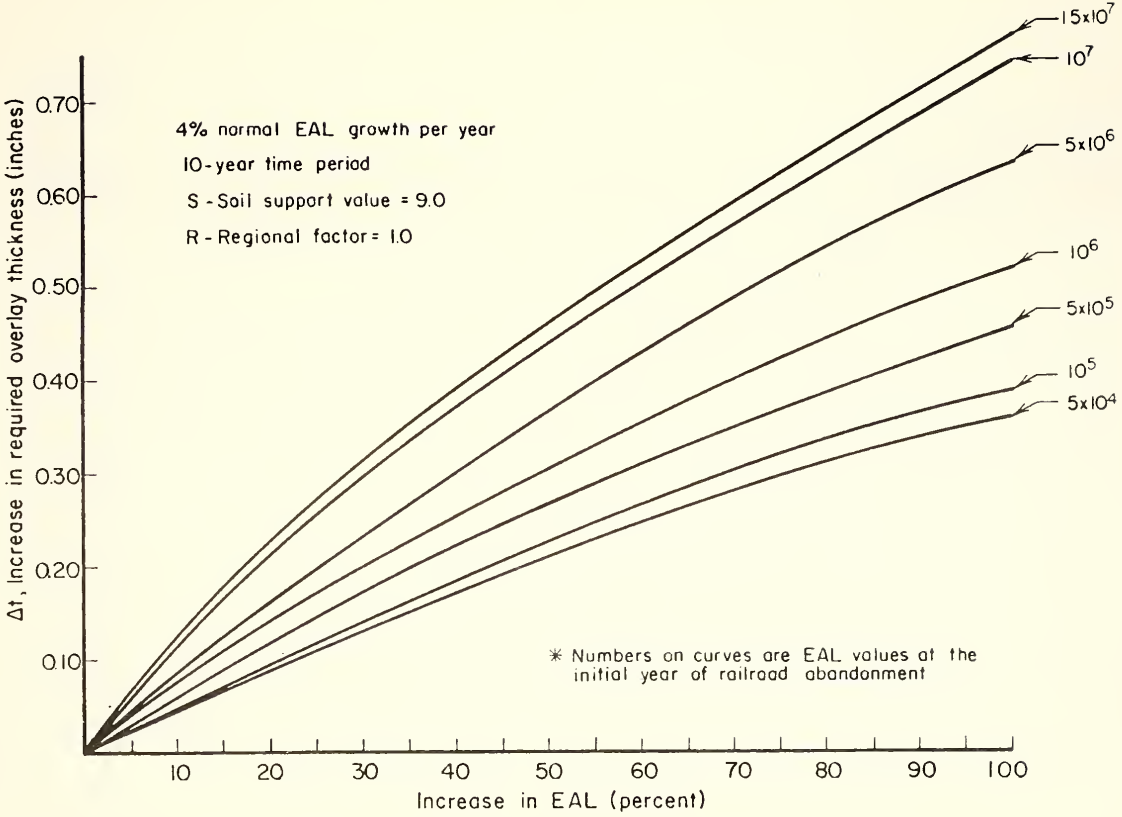


FIGURE 21. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

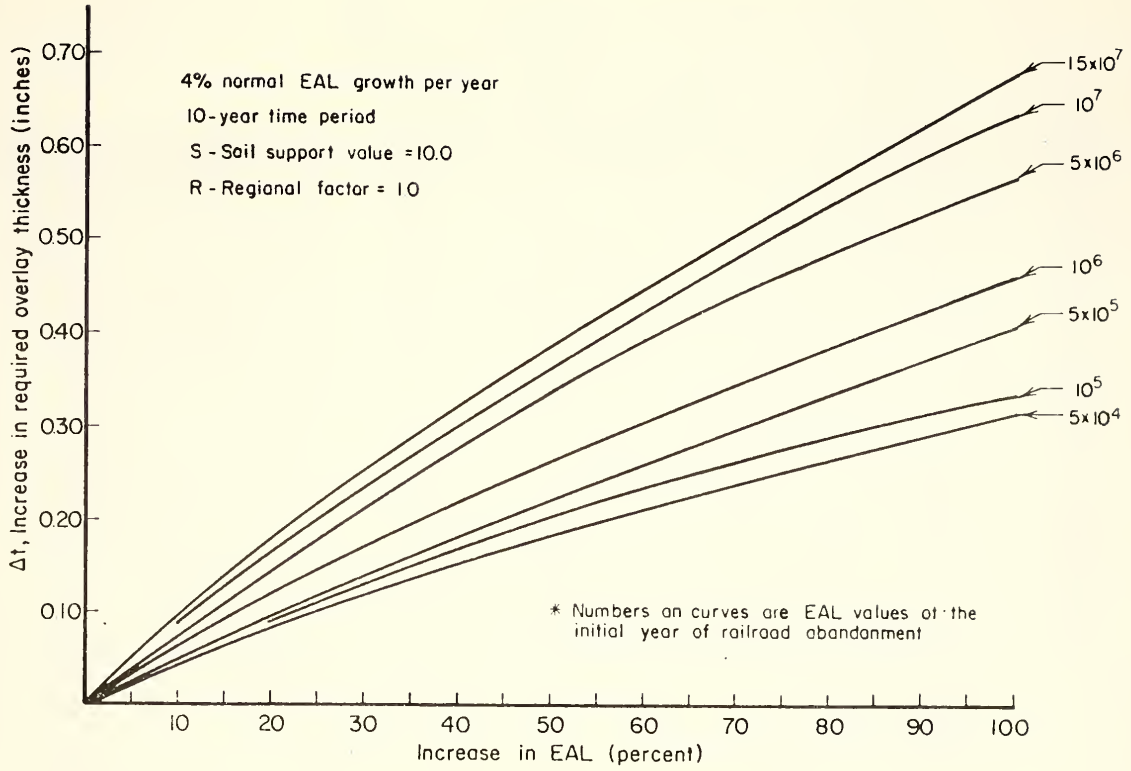


FIGURE 22. EFFECT OF EAL INCREASES ON REQUIRED OVERLAY THICKNESS: FLEXIBLE OVERLAYS ON FLEXIBLE PAVEMENTS

DEVELOPING AN EVALUATIVE METHODOLOGY

The two preceding chapters served to introduce the procedure which represents the nucleus of the evaluative methodology presented in this chapter. This methodology includes not only the previously discussed procedure for measuring railroad abandonment's impact on highway pavements, but also an approach for estimating possible effects of rail service discontinuance on local bridges. Furthermore, the methodology offers techniques which can be employed by user agencies for meeting the data requirements of the procedures' impact formulas or impact graphs. Most importantly, the evaluative methodology includes a means of determining the financial impact of a branch line's closure on the affected highway network.

The methodology, or evaluative system, is evolved by developing techniques to accomplish the following steps:

1. Ascertain the soil support value (S) required in the case of flexible overlays on flexible pavements, and the values of the working stress in concrete (f_t) and the modulus of subgrade reaction (k) which represent necessary input into the case of flexible overlays on rigid pavements.
2. Determine equivalent 18-kip single-axle load applications.

3. Ascertain rail car volumes on the rail line under study and convert this rail traffic to an equivalent number of motor carriers. This volume of trucks must be further converted to an equivalent number of 18-kip single-axle load repetitions.
4. Determine those bridges which would be most severely affected by potential rail service elimination to an area.
5. Assess the costs of pavement resurfacing which would result from increased traffic due to a railroad facility's closing.

Ascertaining the Soil Support Value

The first step in measuring the effect of a rail line's closing on a nearby flexible highway pavement involves the determination of a soil support value (S) for the highway section undergoing analysis. The S-value has no defined relationship to existing test procedures; therefore, a user agency must utilize some means of assigning a value to the S-parameter prior to using the adopted procedure. Several states have established relationships between the soil support value and methods employed for assessing the support strength of a soil, for example, CBR, R-value, Group Index, and Resilient Modulus (M_R) (3). It is suggested that user agencies in each state consult their highway design department in order to discover the appropriate soil support correlations being used in that state.

User agencies in Indiana may determine the S-value based upon the results of a study conducted by Ulbricht in 1967 (25). A five-man soil rating panel was utilized by Ulbricht to obtain ratings ranging from 0.0 to 10.0 for each of the 18 major soil units within Indiana. The mean rating of this panel of soil

experts was taken as the best estimate of the relative performance of a given soil type (25).

To ascertain the soil support value for any highway facility within Indiana, the map entitled, "Engineering Soil Parent Material Areas of Indiana, JHRP, 1950," must be consulted. A copy of this map is reproduced as Figure 31 in Appendix C. By using this map in conjunction with Table 25, which contains S-values for each soil unit displayed on the map and is also located in Appendix C, a soil support value for the study section can be easily determined.

Determining Values of k and f_t

The initial step in evaluating the impact of railroad abandonment on a rigid highway pavement is the ascertainment of two parameters' values - the modulus of subgrade reaction (k) and the working stress in concrete (f_t). The two variables were defined in a previous chapter; thus, this section's purpose is to describe methods for determining values for the two parameters.

The working stress in concrete is defined by AASHO as 0.75 times the modulus of rupture of concrete (S_c). The value of S_c is determined by a test procedure specified in AASHO Designation T-97 after the concrete has cured for a period of 28 days (4). Because various agencies wishing to use the impact graphs may not possess either the time or the technical expertise to perform this test, it is suggested once again that the proper state highway agency be consulted. Possessing a knowledge of the mixture design typically used in rigid pavements of a particular highway classification, highway department personnel can offer an acceptable estimate of the f_t-value.

The selection of an appropriate value for the modulus of subgrade reaction can be accomplished by either actual measurement or correlation with laboratory tests performed on the embankment material (37). Current practices within the states for determining a k-value may be classified into several different categories. These practices include direct measurement of the parameter in the field, correlation with CBR and R-values, and an assumption of the value based upon previous experience in an area.

The measurement of the k-value in the field must be performed in accordance with AASHO Designation T222 using a 30-inch diameter plate (4). The k-value utilized in the development of the AASHO Interim Guide's design procedure is the "gross k", rather than the "elastic k" to which engineers are generally accustomed (37). Therefore, it is important to obtain the proper k-value, the "gross k", when conducting the field test.

Once again, because the majority of groups desiring to use the adopted methodology may not have either the time or the technical know-how to conduct the test mentioned above, it is recommended that an estimate of k be based on Figures 32 and 33 in Appendix D. Figure 32 shows various interrelationships among soil classifications, California bearing ratios (CBR), bearing values, and k-values. Figure 33 displays the correlation between the R-value and the k-value. However, the merit of user agencies directing any inquiries about the estimation of the k-value to the proper state highway department must be reemphasized.

Determining Equivalent 18-kip Single-Axle Load Applications

To use the formulas or graphs presented in this report, mixed traffic, defined as normal highway traffic

that consists of both single and tandem axles of a variety of weights, must be converted to equivalent 18-kip wheel load applications (EAL). As discussed previously, the problem posed by conversion was solved by developing equivalency factors which reduce given single or tandem axles of known weights to equivalent 18-kip single-axle load repetitions. The AASHO Committee on Design has developed flexible pavement equivalency factors for present serviceability index (PSI) levels of 2.0 and 2.5, and for structural numbers varying from 1.0 to 6.0. Rigid pavement equivalency factors were also developed by AASHO for PSI levels of 2.0 and 2.5, and for concrete slab thicknesses ranging from 6 to 11 inches.

A number of methods for converting mixed traffic loads to a sole value of equivalent 18-kip single-axle load applications have been developed by various state highway departments. These methods were derived for conditions occurring within a given state, and in most cases certain assumptions were made in order to prepare a procedure that could be put into use immediately (37). It is recommended that any agency confronted with converting mixed traffic loads to a proper EAL value consult its state highway department in order to discover the method being used in that state. Furthermore, NCHRP Report 128, "Evaluation of AASHO Interim Guides for Design of Pavement Structures" (37), contains a comparison and description of seven commonly-used conversion techniques.

The AASHO Interim Guide for Design of Pavement Structures (3) provides a simplified procedure which can be utilized for calculating EAL values for purposes of design. This simplified procedure was adopted by this research effort and is suggested to user agencies in Indiana as one means of determining EAL values for

highway sections where specific truck weight data is not readily available. The AASHO procedure assumes the following:

1. The traffic volume increases uniformly from the beginning to the end of the design period.
2. The percent of trucks of the traffic volume remains constant over the design period.
3. The axle weight distribution from which the 18-kip rates were developed is constant throughout the design period (3).

The AASHO technique as described in this report is based on information taken from truck weight studies conducted by Indiana, in a manner similar to that of other states, according to the Federal Highway Administration's Instructional Memorandum 50-4-66 entitled, Annual Truck Weight Study (31). In this annual study, one table, Table W-4, summarizes information related to truck weights which has been collected at various stations throughout the State. This information is combined for particular highway systems, such as All Main Rural, Rural Interstate, or Urban Interstate. The AASHO procedure for determining needed EAL values requires the following input data:

1. The average daily traffic (ADT) for a highway section at the time of railroad abandonment.
2. The distribution of traffic by direction and by lanes.
3. The percentage of trucks traveling over a highway section prior to rail service discontinuance, based on a 24-hour traffic volume.
4. The 18-kip axle equivalent rate per 1,000 trucks as obtained from the W-4 loadometer tables for a particular pavement type of a given highway classification.

The method, as explained in the AASHO Interim Guide for the Design of Pavement Structures (3), to compute an EAL value for a specific highway section involves the following steps:

1. Obtain a section's ADT value (ADT_I) for the year just prior to the year when railroad abandonment occurred or will occur. Recent average daily traffic figures are available for every roadway segment in Indiana, as reported in sufficiency ratings (13). If a given section has been divided into several subsections in the sufficiency study, with the subsections possessing different ADT values, a weighted average ADT must be calculated. The average is weighted according to the length of the highway for each traffic volume recorded.
2. Determine the average ADT for a section (ADT_A) from the time of the highway's construction to the time when the rail line under study was closed. A growth factor is utilized in the calculation of this average ADT figure. The year of construction of each highway section within Indiana can be determined from road life records of the Indiana State Highway Commission Planning Department. Based on the assumption of a constant annual rate of traffic growth, the following equations were used in calculating the average ADT value:

$$ADT_A = \frac{ADT_I + ADT_B}{2}$$

$$ADT_B = \frac{ADT_I}{(1+r)^Y}$$

where: ADT_A = the average ADT of a section for the period between the time of the highway's construction and the time when railroad abandonment's effect on the highway is assumed to have begun.

ADT_I = the ADT of the highway section just prior to the rail line's closing.

ADT_B = the ADT of the section when the highway was first constructed.

y = the number of years from the time of the section's construction to the time when service along the rail line under study was discontinued.

r = the annual rate of traffic growth expressed as a decimal fraction.

3. Distribute the average ADT by direction and by lanes for design purposes. Directional distribution is usually made by assigning 50 percent of the traffic to each direction, unless special considerations warrant some other distribution. With regard to lane distribution, most states assign 100 percent of the traffic in each direction to the design lane (3). However, some states have developed lane distribution factors for multilane facilities, and the range of factors often used is given in Table 1.

Table 1. Lane Distribution Factors on Multi-lane Roads

Number of Lanes In Both Directions	Percent of ADT or EAL In Design Lane
2	100
4	80-100
6^{+}	60-80

Source: American Association of State Highway Officials, AASHO Interim Guide for Design of Pavement Structures (Washington, D. C.: AASHO, 1972), Table C-2.5, p. 64.

4. Determine the percentage of trucks using a highway for the year immediately preceding the time when service along the rail line under study was terminated. Recent truck percentages are available for each roadway section in Indiana, again reported in sufficiency ratings (13). The method of calculating a weighted average percentage of trucks for those sub-sections having different values is identical to the technique described previously for ADT values.

5. Obtain the 18-kip axle equivalent rate per 1,000 trucks for the year of analysis, as stated in W-4 loadometer tables. Average rates for all trucks are provided according to highway classifications and for both flexible and rigid pavements within each classification. Similar rates are also given for individual truck types. The figure for all trucks appears at the bottom of the table under the column entitled, "Total All Trucks and Combinations, Probable No.," and across from the row entitled, "18-Kip Axle Equivalents, Rate

Per 1,000". This value for all trucks, when multiplied by the total number of trucks in the design lane for the period between the time of the highway's construction and the time of the rail line's closing, yields the total number of equivalent 18-kip single-axle loads accommodated by the design lane for this same period. As one means of developing a more accurate estimate of loading, AASHO suggests employing 18-kip rates for individual truck types, together with the appropriate truck type percentage as determined from on-site traffic counts. The value for each truck type appears in the same row as the figure for all trucks; however, it appears under the column titled by each truck classification. If the distribution of trucks on a highway study section is suspected to be significantly different than the statewide average, this procedure could be appropriate.

The following example illustrates the above steps constituting the method of determining an EAL value for a highway at the time of service discontinuance on a nearby railroad facility.

Example

Given:

- Rigid pavement.
- ADT_I = 6,000 vehicles per day for each subsection within study section.
- 50 percent directional distribution of ADT_A.
- 100 percent assignment of EAL or ADT_A traveling in one direction to design lane.
- Percent of trucks = 20 percent for each subsection within study section.

- 18-kip rate per 1,000 for all trucks = 603.44 (Other Main Rural Highways classification for the year of analysis).
- r = 6 percent and y = 40 years.

Solution:

1. Average ADT for the 40-year period for both directions of travel:

$$ADT_B = \frac{6{,}000}{(1.06)^{40}} = 583 \text{ vehicles}$$

$$ADT_A = \frac{6{,}000+583}{2} = 3{,}292 \text{ vehicles per average day}$$

2. Average 40-year ADT in one direction = $\frac{3{,}292}{2}$ = 1,646 vehicles.
3. Average 40-year ADT for one direction traveling in design lane:

   1,646 x 100% = 1,646 vehicles.
4. The total number of trucks in one direction traveling in the design lane for the 40-year period:

   1646 vehicles x 20% trucks x 40 years x 365 days/year = 4,806,320 trucks.
5. The total number of equivalent 18-kip single-axle loads in the design lane for the 40-year period:

$$4{,}806{,}320 \text{ trucks} \times \frac{603.44}{1{,}000 \text{ trucks}} = 2{,}900{,}326.$$

The value of 2,900,326 may be utilized as an estimate of EAL_I for use with the impact graphs contained in this report.

Determining Diverted Equivalent 18-Kip Single-Axle Load Applications

A method of converting anticipated traffic diversions caused by railroad abandonment to an equivalent number of 18-kip single-axle load repetitions represents one of the more difficult components of the evaluative system. The previous section described the AASHO simplified procedure for converting traffic flows existing prior to rail service discontinuance to an appropriate EAL value. This section's purpose is to explain one method that can be employed by user agencies for ascertaining the value of EAL_D, the parameter which equals the number of additional load repetitions resulting from a rail facility's closing. The suggested conversion method is not the only one which can be employed by an agency for other methods have been developed and documented (19); however, it was felt that the technique presented in this section may be more accurate and is therefore recommended.

The determination of EAL_D requires accomplishing each of the following steps:

1. Determine rail car volumes for the year of analysis and the rail segment being studied.
2. Convert rail car traffic to an equivalent number of motor carriers.
3. Ascertain those highways which will be affected by a branch line's closing.
4. Convert the number of motor carriers found in step 2 to an equivalent number of 18-kip single-axle load applications, EAL_D.

Determining Railroad Traffic Levels

Information pertaining to rail car movements which were made along a specific branch line can generally be obtained from two sources: 1) the rail users themselves, and 2) rail shipping summaries compiled by USRA or individual railroad companies. Because rail shipping information is typically confidential material, few user agencies will probably have the opportunity of using railroad data which either has been collected by USRA or is based on a railroad company's own records. Thus, the data gathering technique most likely to be employed involves the solicitation of information directly from the shippers themselves, either through personal interviews or by way of self-administered mailback questionnaires.

When requesting traffic information from a rail user, introduction to the purpose of the branch line analysis and use of the data may be necessary to facilitate effective cooperation. Personal interviews are preferable to mailback questionnaires since on-site visits typically result in more information being gathered. However, on-site interviews are generally more expensive than questionnaires, and this should be considered when selecting a data gathering technique.

If self-administered mailback questionnaires are employed by a user agency as a means of obtaining rail traffic data, response rates can be improved considerably by follow-up telephone calls which are placed after questionnaires have been returned incomplete or not returned at all. Information related to rail car volumes, commodities hauled, and tonnages should be based on a firm's business records rather than guesses; however, educated estimates are preferable to no information at all (19).

When collecting shipping information for a specific year from the users located along a rail line under study, the following data related to a firm's inbound and outbound shipments must be gathered:

1. Total number of carloads.
2. Types of commodities transported by the railroad.
3. Average tons per load for each commodity.
4. Origin or destination of railroad shipments.

Following acquisition of the above information from each rail user who would be affected by a railroad facility's closing, a traffic profile can be developed for the rail line undergoing analysis. The line specific traffic profile generated by this step thus serves as the basis for subsequent conversion of rail traffic into an equivalent number of trucks to be assumed by local highways.

Converting Rail Car Traffic to Corresponding Truck Volumes

The technique employed by this research effort to determine the number of trucks which would be required for transporting commodities previously moved via the railroad synthesizes information provided by several sources. The first of these sources, the rail shippers themselves, can easily be solicited for information pertaining to truck/rail conversion factors during the same rail user survey already established for obtaining data related to rail car movements. Industrial traffic managers and elevator operators can provide educated estimates of the number of motor carriers required to transport the amount equal to one rail carload of a commodity. By simply adding more questions to the rail user survey, this information on conversions may be obtained.

Table 2 on page 89 represents the second tool employed by this project for converting rail car volumes to corresponding truck volumes. This table is particularly applicable to those cases where it is suspected that cubic capacity, rather than weight of load, governs the conversion process. As shown by Table 2, a railroad boxcar can transport 1.6 times the amount carried by a truck trailer when cubic capacity is the restricting factor, and the dimensional ratio increases to 2.8 when weight of load is the prime consideration. Therefore, the table's contents are useful as a supplement to the information yielded by the rail user survey.

By utilizing information obtained from the affected shippers, reinforced by the contents of Table 2, it is possible to express the volume of rail cars as an equivalent volume of motor carriers. However, this volume may have to be modified depending on the type and size of truck assumed to be transporting the diverted rail traffic. Since the truck type, and its corresponding axle configuration, to be used for moving diverted rail commodities is not precisely known, it becomes necessary for user agencies to make certain assumptions regarding truck configurations. An assumed truck configuration may not be permitted legally to transport the load size previously specified by rail users; thus, truck volume adjustments which result in a greater number of trucks carrying smaller loads have to be made. The assumptions employed by this research effort with regard to truck sizes and types are described in Part III.

Determining the Affected Highways

The third step in the process of determining diverted equivalent 18-kip single-axle load repetitions

Table 2. Comparison of Typical Boxcar and Trailer Dimensions

Typical Dimensions	Approximate Cubic Capacity	Typical Load Capacity	Ratio of Boxcar to Trailer	
			Cubic Capacity	Weight of Load
		TRAILER		
8'w x 8'6"h x 45'L	3,060 cu.ft.	25 tons	1.0	1.0
		BOXCAR		
10'w x 10'h x 50'L	5,000 cu.ft.	70 tons	1.6	2.8

Source: United States Railway Association, Preliminary System Plan, Vol. I (Washington, D. C.: U. S. Government Printing Office, 1975), Figure 5, p. 154.

involves the distribution of the truck volumes calculated in the preceding step to the local highway system. Before this distribution can occur, the local highway sections most likely to assume the additional trucks caused by a rail line's closing must be delineated. The best source of information for determining those highway sections which could be affected by rail service discontinuance is once again the railroad shippers themselves. Since nearly all firms either ship or receive products by way of trucking as well as rail transportation, traffic managers or similar company personnel represent a good source for learning on which highways railroad abandonment will have the greatest impact. Although the decision process is simplified when the branch line is paralleled by a highway facility, origin and destination data obtained during the rail user survey is particularly helpful when trying to decide which highways will assume the additional truck traffic.

After the affected highways have been identified, user agencies must divide these highways into individual sections according to pavement type - flexible or rigid. Overlay pavement structures are classified according to the type of pavement used in initial construction. Furthermore, the entire section must have been constructed during the same year and should be made as homogeneous as possible with regard to ADT volumes, truck percentages, and number of lanes. Achieving the required homogeneity may necessitate further subdivision of the sections.

Converting Potential Truck Volumes to EAL_D

The final step in the process for determining additional load applications associated with potential rail service discontinuance involves expressing the motor carrier volumes required to transport diverted

rail traffic as an equivalent number of 18-kip single-axle load repetitions. By assuming a particular truck configuration and a corresponding tare weight, the value of EAL_D can be determined from using tables that contain traffic equivalency factors for both rigid and flexible pavements. These traffic equivalency factors were developed by AASHO for terminal serviceability levels of 2.0 and 2.5 and are included in this report as Tables 21 through 24 in Appendix B.

When converting truck volumes to an EAL_D value, it is necessary to assume values for the structural number and the concrete slab thickness. The assumed values are used with the appropriate table in order to obtain traffic equivalency factors which will express potential truck volumes as equivalent 18-kip single-axle load applications. It is suggested that a SN of 3.0 and a D of 9 inches be employed by user agencies for the determination of EAL_D since these values normally yield results which are sufficiently accurate for analysis purposes.

The number of equivalent 18-kip single-axle load applications resulting from motor carriers traveling empty over a study section must also be considered when determining the value of EAL_D. Trucks which are transporting diverted railroad commodities are likely to travel for a portion of their haul without a payload. Equivalent axle loads due to these motor carriers can be calculated by employing the appropriate 18-kip equivalency factors in conjunction with the tare weights and configurations of the trucks assumed to be carrying diverted freight.

Another consideration when determining the value of EAL_D involves the number of equivalent 18-kip single-axle load repetitions which are due to motor carriers transporting loads greater than the legal weight limit.

Results from several studies have indicated that overweight vehicles should be removed from the highways in order to prevent premature pavement failure. Because overloaded trucks create considerable damage to pavement structures, the additional equivalent axle loads from that portion of a truck's payload which exceeds the legal weight limit should be taken into account.

As one means of estimating the EAL applications resulting from overweight motor carriers, Table 3 was prepared by this research effort. This table shows incremental equivalency factors for various axle load groups that exceed the legal weight limit for either single or tandem axles. By multiplying the number of overweight axles which occur in a particular axle weight group times the proper equivalency factor shown in Table 3, the number of additional EAL applications can be determined for the excess payload being transported by an overweight truck. Determination of the number of overloaded axles can be achieved either by using mobile scales to conduct on-site truck weight studies or by using statewide truck weight distributions for a particular highway classification as contained in the appropriate loadometer table. Because the probability of finding overweight vehicles is lower at permanent loadometer stations than at mobile stations, it is suggested that user agencies conduct on-site truck weight studies for determining the number of overloaded axles being assumed by a study section. Once the percentage of overloaded axles has been determined, it is assumed that the same percentage of overweight axles will occur within that group of trucks to be used for transporting diverted rail commodities.

Table 3. Traffic Equivalency Factors for Overweight Axles of Motor Carriers

Axle Load Groups (lbs.)	Representative Axle Load (lbs.)	Equivalency Factors[a]		Equivalency Factors for Overload[b]	
		Rigid	Flexible	Rigid	Flexible
Single Axles					
18,001-18,500	18,250	1.07	1.06	0.07	0.06
18,501-20,000	19,250	1.36	1.31	0.36	0.31
20,001-21,999	21,000	1.96	1.83	0.96	0.83
22,000-23,999	23,000	2.85	2.63	1.85	1.63
24,000-25,999	25,000	4.02	3.70	3.02	2.70
26,000-29,999	28,000	6.29	5.90	5.29	4.90
Tandem Axles					
32,001-32,500	32,250	1.54	0.92	0.05	0.03
32,501-33,999	33,250	1.76	1.03	0.27	0.14
34,000-35,999	35,000	2.18	1.25	0.69	0.36
36,000-37,999	37,000	2.74	1.54	1.25	0.65
38,000-39,999	39,000	3.39	1.88	1.90	0.99
40,000-41,999	41,000	4.15	2.28	2.66	1.39
42,000-43,999	43,000	5.02	2.74	3.53	1.85
44,000-45,999	45,000	6.01	3.29	4.52	2.40
56,000-49,999	48,000	7.73	4.25	6.24	3.36

[a] For $p_t = 2.5$; SN = 3.0 or D = 9 in. depending upon pavement type.

[b] Maximum single-axle load is 18,000 pounds and maximum tandem-axle load is 32,000 pounds.

The following example illustrates the four steps constituting the method for determining a value for EAL_D. It is assumed that the initial information is representative of a single railroad user who is located on the branch line undergoing analysis.

Example

Data obtained from the railroad user survey:

- Type of commodity is fertilizer.
- Origin of shipments is Florida.
- Number of 1973 inbound shipments = 300 rail cars.
- Average payload per rail car = 80 tons.
- Rail/truck conversion factor = 4 trucks per rail car.
- Affected highway section is a flexible pavement.

Solution:

1. Average tons per truckload of fertilizer =

   $= \frac{80 \text{ tons}}{4 \text{ trucks}} = 20$ tons per truck.

2. Assume the truck type employed for transporting the 20-ton load is a 5-axle tractor semi-trailer (3-axle tractor with tandem-axle trailer).
3. Assume the tare weight of the tractor semi-trailer combination is 28,000 pounds.
4. Gross weight of the motor carrier:
   40,000 + 28,000 = 68,000 pounds.
5. Assume the truck's gross weight is distributed over its 5 axles as follows:
   Single axle of tractor = 8,000 pounds.
   Tandem axle of tractor = 30,000 pounds.
   Tandem axle of trailer = 30,000 pounds.
6. Assume a terminal serviceability level of 2.5 and a SN of 3.0 for the flexible pavement section.

7. Increase in equivalent 18-kip single-axle load applications due to one 20-ton truckload of fertilizer:

   EAL = 0.05 + 0.70 + 0.70 = 1.45.

8. Assuming a 10-year analysis period, the increase in equivalent 18-kip single-axle load applications due to fertilizer trucks loaded to the legal weight limit is:

   EAL = 1.45 x 1,200 trucks x 10 years = 17,400.

9. Assuming 1,000 5-axle trucks are traveling unloaded over the study section, the increase in equivalent 18-kip single-axle load applications resulting from the empty motor carriers is:

   EAL = 0.044 x 1,000 trucks x 10 years = 440.

10. Assuming 5 percent of all single axles and 10 percent of all tandem axles are overloaded by 2,000 pounds, the increase in equivalent 18-kip single-axle load repetitions due to additional weight being carried by the overweight trucks is:

    EAL_S = 2200 axles x 0.05 x 0.31 x 10 years
    = 341.

    EAL_T = 4400 axles x 0.10 x 0.36 x 10 years
    = 1584.

    EAL = 341 + 1,584 = 1,925.

11. The 10-year increase in equivalent 18-kip single-axle load applications resulting from over-the-road movement of goods previously transported by way of the railroad is:

    EAL_D = 17,400 + 440 + 1,925 = 19,765.

Evaluating the Impact of Railroad Abandonment on Highway Bridges

Determining possible effects of additional truck traffic on local bridges requires the conducting of an analysis on those highway structures which are likely to assume heavier, more frequent loads when service along a nearby rail line is terminated. The impact of increased truck use on an area's bridges must be estimated in light of the specific situation occurring in that locality. The area specific investigation suggested by this research effort utilizes information associated with the physical condition of the affected bridges, and these data requirements are discussed in the following paragraphs.

Sources of information on local bridge conditions will probably vary from state to state. At the federal level, the U. S. Department of Transportation is presently compiling data provided by the States on those bridges which either carry or cross a Federal-aid highway. Furthermore, DOT is administering a Special Bridge Replacement Program to replace a minimum of ten critically deficient bridges per state (34). The bridges have been classified unsafe due to structural deficiencies, physical deterioration, or functional obsolescence.

In Indiana, data on bridges is available as reported in either sufficiency ratings maintained by the ISHC Planning Department (13) or summary information sheets prepared by the ISHC Bridge Design Department (14). By knowing the following four data items, user agencies can obtain a general idea of a bridge's ability to accommodate additional truck traffic or heavier loads: 1) the year of bridge construction, 2) the bridge's load limit, 3) the structure's roadway width, and 4) the ADT value for the year of analysis. In addition, the Bridge Design Department has calculated

sufficiency ratings which equal 100 percent on structures built to current design standards. From inspecting these ratings, user agencies can identify bridges which are already regarded as being deficient. The identified structures represent those bridges whose present condition will be worsened by potential truck traffic increases due to railroad abandonment.

A third source of information available to user agencies in Indiana involves two lists which have been prepared by the ISHC Bridge Design Department. The first of the two tabulations lists the one hundred bridges in most need of replacement within Indiana while the second is a record of the two hundred bridges in greatest need of repair located throughout the State. It is suggested that these two lists be consulted as a means of determining which of the affected structures might already require repair or replacement. Bridges contained on either of the two lists may have to be upgraded sooner if they are forced to accommodate heavier, more frequent truck passes resulting from closure of a nearby rail line.

Combining data contained in the three sources described in the preceding paragraphs, user agencies should be able to identify fairly accurately the highway structures on which rail service discontinuance will have the greatest impact. An excellent means of supplementing the above information is by asking the railroad shippers themselves during the rail user survey if they are aware of any deficient bridges within the study area. Although this information represents users' subjective opinions regarding bridge conditions on affected highways, the data can be easily collected during the initial data gathering stage, and it permits local input into the bridge identification process.

Assessing the Costs of Pavement Resurfacing

The determination of the financial impact of railroad abandonment involves assessing how much the placing of the additional required asphaltic concrete overlay will cost to local or state governments. The required expenditure can easily be calculated once the current price of asphaltic concrete resurfacing has been ascertained. Therefore, it is suggested that user agencies consult their state highway department to discover the appropriate prices of commonly-used asphaltic concrete resurfacing materials.

In Indiana, the average bid price for materials related to highway construction can be determined by referring to the annual report prepared by the Special Provisions Group of the Indiana State Highway Commission entitled, Catalog of U.P.A. Prices for Roads and Bridges (12). By consulting this document for the appropriate year, user agencies in Indiana can obtain the asphaltic concrete resurfacing price which permits the thickness of flexible overlay determined from the impact graphs or impact formulas to be expressed as a monetary amount.

PART THREE

PROCEDURAL DEMONSTRATION

TWO CASE STUDIES

INTRODUCTION

The purpose of this section is to demonstrate use of the procedure developed by this study for evaluating the effects of railroad service discontinuance on local highways and bridges. The section is also designed to indicate how existing data sources may be utilized in determining necessary information such as rail car volumes and highway characteristics. The demonstration is included as a working example of the procedure that shipper groups, local communities, or state governmental agencies can follow in assessing railroad abandonment's highway impact.

The following chapter of this section provides background information on the areas surrounding the two rail lines selected for detailed study. The two rail segments chosen for analysis are: 1) the portion of USRA Line Number 429 from Decatur to Portland, and 2) USRA Line Numbers 589 and 590 situated between the cities of Madison and North Vernon. The affected counties include Adams and Jay counties for the first case study and Jennings, Jefferson, and Scott counties for the case of Line Numbers 589 and 590.

Chapter 11 discusses the results of a survey of thirty-three rail users located within the study areas that was conducted in order to determine the transportation alternatives available to these shippers if rail service to their businesses was terminated. The survey was accomplished by personally visiting and talking to each of the shippers. The survey's results were felt to be informative since the opinions expressed by the

thirty-three interviewees might be indicative of the opinions of rail users in other areas confronted with a similar abandonment dilemma.

The results of the procedure's use for each of the areas undergoing analysis are described in Chapter 12. The expected level of impact on the highway network caused by the closings of Line Numbers 429 and 589-590 is shown through the application of the methodology developed by this project. The chapter demonstrates how Figures 4 through 22, found on pages 52 through 73 can be employed to assess the effects of railroad abandonment. In addition, the chapter includes a discussion of the possible impact of heavier, more frequent truck traffic on each area's bridges.

A DESCRIPTION OF THE STUDY AREAS

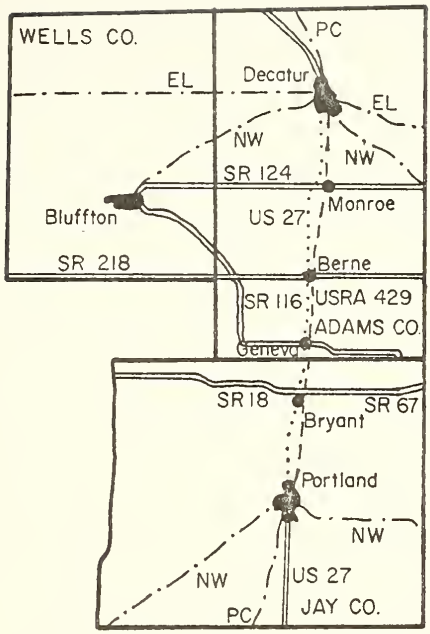
The purpose of Chapter 10 is to provide information on the affected counties - including their highways, railroad facilities, and bridges - located within the two case study areas. The reasons underlying the selection of each of the two areas have been mentioned previously in Chapter 4.

County and Community Features

Two Indiana counties, Adams and Jay counties, would be directly affected by any discontinuance of railroad service along USRA Line Number 429. The two counties are located in eastern Indiana, as shown by Figure 23 on page 102. The area, excluding the cities of Decatur and Portland which constitute the termini of the rail segment, is primarily agricultural in nature with manufacturing activity along Line Number 429 being concentrated in the community of Berne. The 1970 population of Adams County was 26,871, and the county's population grew at an annual rate of 0.90 percent during the last ten years (30). The 1970 population of Jay County is recorded at 23,575, and during the decade of the 1960's, its population grew by only 0.44 percent each year (30).

Four communities situated along the 27.5-mile length of Line Number 429 will lose direct rail service if railroad abandonment is implemented. These four towns are the communities of Berne, Bryant, Geneva, and Monroe; their locations within each county and with regard to Line Number 429 is shown in Figure 24. Berne, the largest of the four towns with a 1970 population of

FIGURE 23. LOCATION OF FIRST CASE STUDY AREA IN INDIANA



- - - - - - - USRA Line No. 429

. . . . . U.S. Highway 27

—·—·—·— Other Railroad Lines

═══ Other State and U.S. Highways

FIGURE 24. THE FIRST CASE STUDY AREA: ADAMS AND JAY COUNTIES

2,988, contains a variety of manufacturing firms which utilize rail service. Each of the towns of Geneva and Monroe contains a single principal manufacturing company - Naas Foods, Inc. in Geneva and Automatic Sprinkler Company in Monroe - that continues to use rail transportation to any extent. The other firms located in the four communities which continue to require rail access serve primarily as suppliers to the agricultural interests of Adams and Jay counties. These firms include milling companies, fertilizer distributors, lumber companies, and coal suppliers. The Adams County Farm Bureau operates elevators at Berne, Monroe, and Geneva. The Bureau is owned by 2,259 farmers who have invested over one million dollars in equipment and facilities (16). The Co-op's 1973 level of business activity surpassed ninety-five million dollars which provides an idea of the agricultural character of that county in particular.

The second case study area consists of Jennings and Jefferson counties which contain USRA Line Numbers 589 and 590. Several highways within Scott County would also be affected by the closing of the North Vernon to Madison rail segment; thus, Scott County was also included in an analysis of abandonment's highway impact within this section of southeastern Indiana. The location of the three counties with respect to the remainder of the state is depicted in Figure 25. The 1970 population of Jennings County was 19,454, and the county's population is increasing at an annual rate of 1.21 percent (30). North Vernon, the largest community in Jennings County with a 1970 population of 4,582, would retain rail service via the east-west Baltimore and Ohio main line if Line Number 589 is abandoned. Vernon, the county seat, contains one major manufacturing company - Jenning's Industries, a manufacturer of wooden porch swings.

FIGURE 25. LOCATION OF SECOND CASE STUDY AREA IN INDIANA

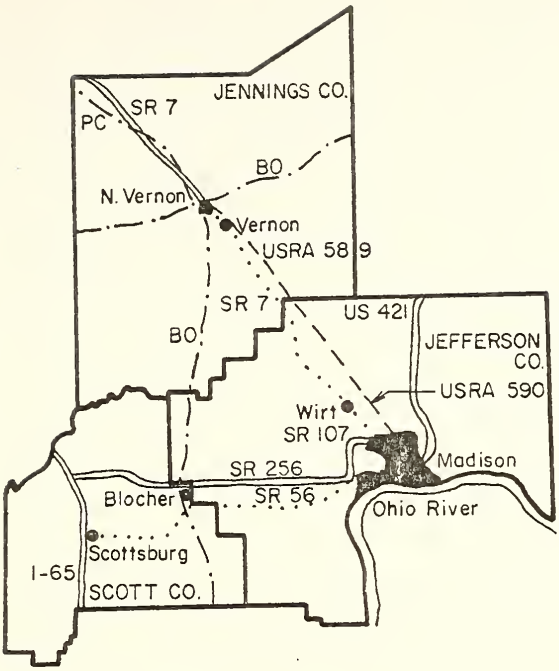
Jefferson County had a 1970 population of 27,006 and the county grew at an annual rate of 1.16 percent in the years from 1960 to 1970 (30). The county's largest city and seat of government is Madison, a town of 13,081 persons in 1970 (30). This community, which is located on the Ohio River, would be the most severely affected town in this study area if rail service along Line Numbers 589 and 590 is discontinued. Madison contains diverse industrial activity, ranging from construction equipment to scrap metal. Although several Madison-based companies no longer ship or receive products via the railroad, other companies in the town continue to depend upon rail transportation for moving those products which cannot be economically trucked. The importance of agriculture in Jefferson County appears to be declining as evidenced by the closing of the Indiana Farm Bureau Co-op in Madison and by the 2.5 percent annual decline in rural population which occurred from 1960 to 1970 (30).

The 1970 population of Scott County is recorded at 17,144, and during the 1960's, the county's population increased by 1.59 percent annually (30). The county seat of Scottsburg is located at the junction of Interstate 65 and State Highway 56.

A map indicating the location of the aforementioned communities in the three-county region is presented in Figure 26. The figure on page 107 also contains the major highways and rail lines found within the study area.

Rail Line Characteristics

The portion of USRA Line Number 429 selected by this research effort as a case study is a part of the Ridgeville Secondary Track, formerly owned by the Pennsylvania Railroad Company. The rail segment being



- - - - - - - USRA Line Numbers 589 and 590

. . . . . State Highways 7 and 56

—·—·—·— Other Railroad Lines

═══ Other State and U.S. Highways

FIGURE 26. THE SECOND CASE STUDY AREA : JENNINGS, JEFFERSON, AND SCOTT COUNTIES

analyzed extends from Portland, Indiana to Decatur, Indiana for a distance of 27.5 miles in Adams and Jay counties. The location of the branch line is shown on Figure 24. It is a subsection of a longer segment investigated by USRA during 1974 and the early months of 1975. In March 1975, the Governor's Rail Task Force recommended to USRA that the branch line undergoing viability analysis be reduced from its original length of 37.7 miles, the distance from Decatur to Ridgeville, Indiana. This shortening of the line's length to 27.5 miles decreases traffic along the rail line by only one rail car for the year 1973, and the Task Force felt that this action presented a more accurate picture of the line's utilization (10). The segment of USRA Line Number 429 being studied continues south to Richmond, Indiana and north to Adams, Indiana.

If abandonment of Line Number 429 is implemented, the segment's terminal cities, Decatur and Portland, will retain rail service via other rail lines. Decatur would be served by the Norfolk and Western line to Delphos, Ohio and by a 1.1-mile section of the Erie Lackawanna rail line that extends from Chicago, Illinois to Marion, Ohio. This short segment has been included in the Final System Plan (36) solely to accommodate shippers in Decatur since the remainder of this Erie Lackawanna track was excluded from the ConRail network. The city of Portland would retain rail service by way of a Norfolk and Western facility which extends eastward to Sandusky, Ohio and westward to Frankfort, Indiana.

The segment's economic analysis, conducted by USRA, indicated a need for track upgrading to meet the requirements of the Federal Railroad Administration's (FRA) minimum safety standards, namely Class I track possessing a maximum safe operating speed of 10 miles per hour. Based on information available to USRA, this

upgrading would demand the replacement of nearly 190 crossties along the Decatur to Portland rail segment, an average of 7 crossties per mile (36).

During 1973 the Penn Central Transportation Company originated and terminated 742 carloads along the segment's 27.5-mile length, or about 27 carloads per mile. The Association's economic analysis stated that a 114 percent increase in rail traffic or a 63 percent rate increase would be necessary for achieving viability (36). The above conclusions are based on 156 round trips being made annually on the segment, an average of 3 switches per week. Furthermore, information given to USRA with regard to the potential of the line's experiencing traffic growth indicated a projected traffic level significantly less than that required for economic viability (36).

The second case study involves a branch line divided into two rail segments by USRA during its analysis - USRA Line Numbers 589 and 590. The Governor's Rail Task Force has frequently stated its belief that the two lines cannot be investigated adequately except as a single rail line, and this point of view was adopted by this research effort (10). Nevertheless, since USRA has collected and summarized data for each rail line individually, discussions of the two segments are presented separately in the following paragraphs.

USRA Line Number 589 is part of the Columbus-Madison Secondary Track, formerly owned by the Pennsylvania Railroad Company. As shown by Figure 26, the rail segment connects North Vernon, Indiana with North Madison, Indiana, a distance of 23.8 miles in Jennings and Jefferson counties. The line continuing northwestward to the towns of Scipio and Columbus, Indiana, USRA Line Number 588, represents another rail segment slated for omission from the ConRail network. The southeastward extension to Madison is Line Number

590, and it is described further in a later paragraph of this section. If service is terminated along Line Number 589, North Vernon would retain railroad accessibility since the community is also served by an east-west Baltimore and Ohio main line. Moreover, the community has additional rail access via a branch rail line extending to the cities of Jeffersonville, Indiana and Louisville, Kentucky.

According to the analysis conducted by USRA, as stated in the Final System Plan, the North Vernon to North Madison rail segment would demand extensive upgrading of the track in order to meet FRA minimum safety standards. Based upon data supplied to the Association, the agency foresees a need to replace 11,715 crossties, or nearly 500 crossties per mile (36).

Line Number 589 generated a loss of $197,278 in 1973 according to the Association's economic analysis (36). This loss is based upon an average of 3 switches being made each week, or 156 round trips for the year. Furthermore, the investigation used a figure of 1,000 carloads as the traffic volume originating and terminating on the rail line in 1973. The recovery of this deficit would necessitate either a twofold increase in traffic or a 69 percent rate hike (36).

Also a part of the Columbus-Madison Secondary Track, USRA Line Number 590 connects North Madison to Madison, as shown by Figure 26. This 2.0-mile segment represents the end of the previously mentioned secondary track; thus, the city of Madison is without rail accessibility if Line Numbers 589 and 590 are abandoned.

Similar to the case of Line Number 589, USRA specified a need for upgrading the track constituting this 2.0-mile segment to FRA Class I standards. Based on information available to the Association, track

improvement would involve the replacement of 1,278 crossties, an average of approximately 639 crossties per mile (36). The Association's economic analysis, using a figure of 1 round trip per week, depicted a loss of $14,638 being generated by the segment in 1973. In order for Line Number 590 to become an economically viable line once again, a 66 percent increase in traffic or a 28 percent rate increase would be necessary (36).

Various public agencies have been encouraged by USRA to recommend alternative uses of railroad rights-of-way once rail service along light-density branch lines is discontinued. With regard to Line Number 590, the Bureau of Outdoor Recreation, a branch of the U. S. Department of Interior, has recommended that the segment be preserved for recreational purposes since the line possesses historical significance and unique characteristics (36). Line Number 590 was part of the first railroad west of the Allegheny Mountains and has the world's steepest railroad grade, 5.69 percent. The rail line passing through two tremendous cuts in solid limestone was excavated during 1835. The "incline", the name given to the steep section of the rail segment by Madison townspeople, descends 413 feet in slightly more than a mile.

Highway Characteristics

The major highway in the case study area composed of Adams and Jay counties is U. S. Highway 27, and this facility parallels closely Line Number 429 for its entire length from Decatur to Portland. If Line Number 429 between the two cities mentioned above is closed, U. S. Highway 27 appears to be the facility which would assume the largest part of the traffic diverted from the

abandoned branch line. Figure 24 shows the highway's location within the two-county region.

U. S. Highway 27 is a two-lane facility with a predominant width of roadway of 24 feet. The major exception to this 24-foot width is within the town of Berne where the roadway widens to 36 feet. Average travel along the rural sections of U. S. Highway 27 varies from 5,000 to 6,000 vehicles daily, with 5 to 10 percent of this daily traffic consisting of commercial vehicles. For the more urbanized sections within the towns of Berne and Geneva, average daily travel increases to approximately 7,000 vehicles with a corresponding growth in the percentage of commercial vehicles, namely, to 18-20 percent (13). The pavement composition of U. S. Highway 27 from Portland to Berne consists of bituminous overlays above the original concrete or rigid pavement structure. On the other hand, the segment located between Berne and Decatur has a pavement composed of several asphaltic concrete overlays on a nonrigid base.

Unlike the previously described situation of U. S. Highway 27 in which a single highway accommodates the vast majority of additional truck traffic resulting from railroad abandonment, the three counties of the second case study region contain several highways that could be affected by the closing of Line Numbers 589 and 590. The two highways described in the following paragraphs are the facilities regarded as being most likely to assume diverted rail freight from the North Vernon to Madison branch line. Highway selection was based on information gathered from interviews of the rail users who are situated in this study region, and the location of the highways is shown in Figure 26.

State Highway 7 roughly parallels USRA Line Number 589 for the 25-mile distance from North Vernon to North Madison. The road is a two-lane facility having a width which varies from 22 to 24 feet. Rural sections of State Highway 7 are traveled daily by an average of 2,500 vehicles although the average daily traffic (ADT) increases to 5,000 vehicles in urban sections of North Madison and to 8,500 vehicles in similar more developed areas within Vernon. The percentage of trucks using this highway varies from 5 percent on rural sections to approximately 15 percent in more urbanized areas of Vernon and Madison (13). For the 17-mile section of State Highway 7 from North Vernon to the community of Wirt, the pavement structure consists of asphaltic concrete overlays above the rigid roadway originally constructed in 1931. However, for the section between Wirt and the northern city limits of Madison, the pavement structure must be classified as flexible overlays above a flexible pavement. This segment was originally constructed in 1937 of rock asphalt on a nonrigid base, and the highway was repaved in 1951 with a rock asphalt surface treatment.

The section of State Highway 7 which connects North Madison and Madison, in the same manner as Line Number 590, warrants separate mention because of the roadway's extreme geometric characteristics. The highway possesses sharp curves and steep grades similar to the steep grade of the 2.0-mile rail segment. The speed limit for this portion of State Highway 7 decreases to 25 and 30 miles per hour in certain locations with trucks forced to travel at even lower speeds due to the severe grades. The ability of this segment to accommodate additional truck traffic from a capacity viewpoint is suspect, and this problem deserves further investigation.

A second highway which is likely to assume additional trucks transporting commodities previously moved via the railroad is State Highway 56, situated in Jefferson and Scott counties of the study area. State Highway 56 serves as a major access route from Madison to Interstate 65. The facility would also be used by Madison-based shippers for trucking commodities to the Baltimore and Ohio rail line in Blocher, Indiana. Blocher is the closest community to Madison which will retain direct rail service; thus, shippers could elect to truck those commodities requiring railroad transportation for the 14-mile distance to Blocher, followed by reloading of the freight upon rail cars for long-distance rail movement.

State Highway 56 has a predominant width of 22 feet for the rural roadway sections in Jefferson and Scott counties. In the more urbanized areas of Madison and Scottsburg, the facility widens to 37 feet. The 1973 average daily traffic for rural segments was 2,000 vehicles while urban sections in Scottsburg, Hanover, and Madison were traveled by nearly 7,500 vehicles daily in the same year (13). The percentage of trucks using State Highway 56 is very similar to State Highway 7. Approximately 5 percent of the traffic on rural sections involves commercial vehicles, and this figure increases to 15 percent for urban sections (13).

The pavement structure of the segment of State Highway 56 in Jefferson County is once again flexible overlays on a rigid pavement. However, the pavement's composition changes to flexible overlays above a flexible pavement in Scott County, specifically, several layers of bituminous asphalt above a nonrigid base.

Bridge Characteristics

Since one phase of this research effort deals with the impact of railroad abandonment on highway bridges, age and design features of the structures likely to be affected by additional truck traffic should be investigated. This section describes the characteristics of the bridges located on the affected sections of U. S. Highway 27, State Highway 7, and State Highway 56.

The segment of U. S. Highway 27 from Decatur to Portland contains 6 bridges spanning various rivers and creeks in the first case study area. As shown by Table 4 on page 116, 5 of the 6 have been constructed during the past 11 years. The predominant roadway width of each bridge is 33 feet although the structures over Blue and Boram Creeks are somewhat wider. Average daily traffic crossing the 6 bridges in 1973 ranged from a low of 4,700 vehicles to a high of 7,700 vehicles. Each of the 6 structures is capable of supporting the maximum legal load permitted on Indiana's highways (14).

Unlike the structures located along U. S. Highway 27, the bridges situated on the study sections of State Highways 7 and 56 have been in service for many years. Characteristics of those bridges located on the two highways undergoing analysis are discussed in the following paragraphs.

Referring to Table 5, 10 structures are shown to be situated on the North Vernon to Madison section of State Highway 7. The present ages of the 10 bridges in Jefferson and Jennings counties vary from 10 years to 75 years, including 5 that have been carrying traffic for more than 45 years. According to records maintained by the Bridge Design Department of the Indiana State Highway Commission, each structure found on the study section of State Highway 7 is capable of withstanding

Table 4. Bridges Located on U. S. Highway 27

Bridge	Year of Const.	Load Limit (Tons)	Bridge Length (Ft.)	Rdwy. Width (Ft.)	1973 ADT (2-way)
Bear Creek	1967	16	149	33	6100
Limberlost Creek	1967	16	164	33	4700
Loblolly Creek	1966	16	156	33	4800
Wabash River	1967	16	312	33	6900
Blue Creek	1964	16	110	41	5500
Boram Creek	1937	16	28	38	7700

Source: Indiana State Highway Commission, 1973 Sufficiency Ratings of Indiana Highways (Indianapolis, Ind.: Planning Dept., ISHC).

Table 5. Bridges Located on State Highways 7 and 56

Bridge	Year of Const.	Load Limit (Tons)	Bridge Length (Ft.)	Rdwy. Width (Ft.)	1973 ADT (2-way)
		Indiana 7			
Crooked Creek	1900	16	37	24	4800
Dean Branch	1957	16	28	46	4800
Big Clifty Creek	1957	16	26	39	4400
Harbath's Creek	1961	16	79	37	4400
Hensley Creek	1959	16	36	32	3500
Middle Fork Creek	1930	16	206	24	2400
Big Creek	1927	16	137	20	2400
Camp Creek	1965	16	64	33	2400
Big Graham Creek	1930	16	174	22	2500
Muscatatuck River	1930	16	423	22	6300
		Indiana 56			
Big Springs Creek	1931	16	84	24	5400
Clifty Creek	1931	16	93	20	8100
Crooked Creek	1927	16	66	20	8100
Penn Central R.R.	----	12	63	30	8900
Pigeon Roost Creek	1938	16	118	28	5300
Kimberlin Creek	1964	16	85	31	3900
Stucker Creek	1924	16	172	20	2600
White Eye Creek	1958	16	40	28	2900
B & O R.R.	1926	16	90	20	2900

Source: Indiana State Highway Commission, 1973 Sufficiency Ratings of Indiana Highways (Indianapolis, Ind.: Planning Dept., ISHC).

Indiana's maximum legal load limit (14). Several of the bridges may be regarded as possessing narrow roadway widths, specifically, the two in Jennings County plus the structure spanning Big Creek in Jefferson County. The bridge over the Muscatatuck River outside Vernon was carrying the greatest amount of traffic in 1973, nearly 6,300 vehicles daily (13). A point to be noted is that each of the 5 narrower structures was constructed prior to 1930.

The segment of State Highway 56 from Madison to Scottsburg is similar to State Highway 7 for it also contains several old, narrow bridges. A total of 7 bridges span creeks in the area composed of Jefferson and Scott counties, as shown by Table 5. In addition, two structures cross rail lines in the two-county region. Two bridges located along State Highway 56 in Jefferson County were built during 1931 and have roadway widths of 24 feet. Structures spanning Crooked Creek and Stucker Creek were constructed in 1927 and 1924, respectively, and each has a width of only 20 feet. The 2 bridges crossing railroads have been in service for many years and have been included in Indiana's current Capital Improvements Program for immediate replacement. According to traffic figures obtained from Indiana's sufficiency ratings, the structures spanning Clifty and Crooked Creeks are the most heavily-traveled bridges in the area since each carries more than 8,000 vehicles daily (13). Only 1 bridge of the 9 structures situated along this segment of State Highway 56 is posted for a lower load limit than the maximum legal limit for Indiana. This single bridge is the one crossing Line Number 590 in Madison, and it is posted for a maximum single-axle load of 12 tons (14).

ANALYSIS OF RAIL USER INTERVIEWS

Purpose of the Interviews

When rail revenue service to an area is eliminated, the local manufacturing firms, grain elevators, and other rural producers must seek alternative modes for transporting those commodities previously moved by rail. The question which must be answered involves what actions are likely to be taken by a rail user confronted with impending railroad abandonment. Will the shipper shift to an alternative mode of transportation, or will he perhaps elect to cease operations completely, as a direct result of the additional transportation costs arising from the new mode? The approach of conducting personal interviews of a selected number of rail users was regarded by this research project as being the preferred means of answering the question listed above.

Before assessing the impact of railroad abandonment on the highway network, a knowledge of which highway facilities are most likely to assume the diverted rail traffic must be acquired. To be specific, two options related to motor carrier transportation are generally open to rail users along a line being proposed for abandonment. The first option involves shipping a commodity, once transported by rail, by truck to a nearby community which has retained rail service. If the shipper selects this option, he will incur additional transshipment costs when he reloads from the truck onto a rail car at the rail head. On the other hand, the rail user may choose the second option which consists of shipping a commodity for the entire length

of haul by motor carrier. Although transportation costs for long truck hauls may be higher than railroad costs, the increased reliability and faster service afforded by trucks could compensate for the higher rates. As a means of determining which of the above options would be chosen by the rail users in the affected areas, personal interviews were arranged with a selected group of shippers along each of the two case study lines.

The personal interview technique was adopted rather than the self-administered mailback questionnaire for several reasons. It was felt that the response rate for a mailback questionnaire could be expected to be low since these persons, as users situated on a rail line being considered for abandonment, have already been subjected to numerous questionnaires and surveys.

The technique of on-site interviews also possessed other advantages. An interview presented an excellent opportunity to learn firsthand about railroad abandonment from those people who would be affected by its consequences. The frustrations of poor service, inadequate supplies of rail cars, and frequent freight damage could be more adequately expressed in an interview than in any other vehicle of communication. Another advantage involved the opportunity of personally inspecting those roads and bridges which might be forced to accommodate additional truck traffic within the affected areas. This personal inspection could be accomplished during the same period of time that the on-site interviews were being conducted.

In conclusion, the comments made by a rail user in a face-to-face discussion are valuable for the glimpse of the human aspects of railroad abandonment

which they offer. The results of the interviews are informative since the opinions held by the users on such topics as the level of rail service which should be provided by a railroad company may be indicative of the opinions of rail users in other areas faced with possible abandonment.

Determination of Rail Users in the Affected Areas

The first step in the interview process involved the determination of rail users along both the Decatur to Portland and North Vernon to Madison rail segments. A report, U.S.R.A. Segments in Indiana: State Analysis and Recommendations (10), contained a list of the rail shippers along each of the lines under study. From this report, thirty-three users were found to be located along Line Number 429 in the communities of Berne, Geneva, Bryant, and Monroe. In a similar fashion, twenty-six rail shippers were determined to be located along Line Numbers 589 and 590 in the towns of North Vernon, Wirt, Vernon, and Madison. Table 6 depicts the number of rail users located in each community for the two lines undergoing analysis.

After discovering who the rail shippers were in each community, the next step consisted of identifying for each user those commodities transported by rail. Several sources were used for this task. The first consisted of a summary of responses from a previous questionnaire conducted by the Center of Urban and Regional Analysis located at Indiana University. This summary listed particular characteristics, including the major commodities shipped or received by a rail patron, for nineteen of the rail users located along the North Vernon to Madison line and for thirteen of the shippers situated on Line Number 429. Since

Table 6. Location of Railroad Users Within the Two Case Study Areas

Community	County	No. of Railroad Users
	USRA Line No. 429	
Bryant	Jay	5
Geneva	Adams	9
Berne	Adams	15
Monroe	Adams	4
Total		33
	USRA Line No. 589-590	
North Vernon	Jennings	7
Vernon	Jennings	1
Wirt	Jefferson	1
Madison	Jefferson	17
Total		26

Source: Governor's Rail Task Force, State of Indiana, U.S.R.A. Segments in Indiana: State Analysis and Recommendations, Vol. 2 (Bloomington, Ind.: The Center of Urban and Regional Analysis, Indiana University, 1974) pp. 8-9, 23-24.

this summary did not contain responses for all the rail users specified in the report mentioned in the previous paragraph, a second source was referred to in an attempt to find additional information.

This second source of information consisted of a list of manufacturers and wholesalers operating in the communities between Decatur and Portland and between North Vernon and Madison. This list, compiled by Mr. Edward Lutz of the Indiana Department of Commerce, aided in identifying the principal rail-transported commodities for those users not mentioned in the Indiana University questionnaire summary. However, since all rail users identified in the report, U.S.R.A. Segments in Indiana: State Analysis and Recommendations (10), had not been covered in the two preceding sources, a third report was consulted.

Volume III of the February 1975 document, The Public Response to the Secretary of Transportation's Rail Services Report (16), was the final reference consulted in this project's effort to determine what commodities were being shipped by rail from those firms identified as rail users. This report, prepared by the Rail Services Planning Office, includes traffic profiles on each rail line proposed for rail service discontinuance by the U. S. Department of Transportation. Because both lines under study by this research project had been considered as being expendable by the Department of Transportation, additional information on user-specific rail commodities could be obtained.

By combining the information found in the previously discussed reports, a fairly accurate description of who was using the railroad and what commodities were being transported via rail by each user could be prepared. From these fifty-nine rail patrons

identified in this phase of the interview process would come the selected group of shippers to be visited.

Selection of Rail Users to be Interviewed

The results of the previous phase of the interview process had been a list of fifty-nine rail users, along with the principal commodities being transported by each shipper, for the two case study areas. Because a number of these firms could be transporting only a few rail cars each year, it was felt to be unnecessary to speak with each of the fifty-nine rail shippers. Therefore the approach described in the following paragraphs was used for narrowing down to an adequate number those rail patrons to be visited.

The initial step in the selection process involved matching 1973 incoming and outgoing rail shipments for a community, representing data taken from the Penn Central Traffic Tapes, to specific users in that community. This step also incorporated the knowledge of what each company was primarily shipping via the railroad - information acquired from the three sources cited in the preceding section. By a procedure of matching major commodity flows into and out of a community to the companies located there, the larger users of the railroad line could be adequately denoted. Since a change in rail shipping patterns by these larger users would have a more significant impact than for other rail shippers, the decision was made to visit each major user of the railroad.

Having removed the principal rail users from the list of fifty-nine rail patrons, the remaining shippers for each community were classified according to the nature of a firm's rail shipments, for example, lumber products. These rail users were

labeled as "minor" shippers because the number of rail shipments associated with each patron were suspected to be small. To interview each of the "minor" rail users within a locality was felt to be an inadequate utilization of the time and money allotted to this research effort. Therefore, a technique was developed whereby each "minor" rail shipper selected for interviewing was chosen from a randomly ordered list of "minor" users who are located in the same community and who share a similar type of business activity. To illustrate how this procedure was actually used, an example follows.

Five shippers cited as being rail users by the report, U.S.R.A. Segments in Indiana: State Analysis and Recommendations (10),composed a group of the most likely firms within Berne, Indiana to receive inbound carloads of agricultural chemicals and fertilizer. From the traffic profile of Line Number 429 in the report, The Public Response to the Secretary of Transportation's Rail Services Report (16), two of the five shippers, Riverside Inc. and the Adams County Farm Bureau Co-op, were identified as being large receivers of fertilizer and other agricultural chemicals. These two firms were therefore regarded as primary rail users, and to interview them was considered essential. The remaining three firms - Berne Hiway Hatchery, Lehman Feed Mill, and Custom Farm Services - were classified as "minor" rail shippers, and only one interview from the three was considered to be necessary. These three firms were randomly ordered with the first one chosen representing the company to be visited. The technique of using a random order was adopted in order to prevent any consequences of survey bias which might occur in the field. In other words, if the first user could not be

interviewed for some reason while in the field, a second potential interviewee had already been randomly predetermined from using the order technique. This statistical method eliminated having to make arbitrary and possibly biased decisions while in the field.

By using the selection procedure described in the preceding paragraphs, thirty-two shippers, sixteen rail users located along each line, were chosen for on-site visits. As a means of explaining the interview's purpose, each of the thirty-two firms was mailed a letter describing the reasons for holding the interview. In addition, a stamped, self-addressed post card was enclosed with each letter. This enclosure permitted a firm's president or manager to name the person who would be interviewed plus a suitable date and time for the meeting. A copy of the letter which was mailed to the rail shippers is included in Appendix E. Sixteen post cards, representing 50 percent of the total mailed, were returned. Nevertheless, it was decided to visit each of the rail users who had been contacted in order to increase the amount of information gathered from the interviews. There was a possibility that some companies may have simply forgotten to return the post card for one reason or another.

The rail user interviews were conducted during the week from July 28, 1975 to August 1, 1975. Eighteen shippers in the communities of Bryant, Geneva, Berne, and Monroe were asked their opinions on the possible discontinuance of service along Line Number 429. Fifteen users in the towns of North Vernon, Wirt, Vernon, and Madison discussed the business actions available to their firms if rail service along Line Numbers 589 and 590 is discontinued. The shippers visited in each town are listed in Tables 7 and 8. In addition, a copy of the questionnaire form

Table 7. Railroad Users Interviewed Along USRA Line No. 429

Railroad User	Major Commodity Shipped Via the Railroad	Location of User
Occidental Chemical Co.	Fertilizer	Bryant
Bryant Elevator	Grain, soybeans	Bryant
Empire Gas Co.	Bottled gas	Bryant
Nass Foods, Inc.	Canned tomato products	Geneva
Geneva Milling Co.	Grain, fertilizer	Geneva
Geneva Lumber Co.	Lumber	Geneva
Adams Co. Farm Bureau Co-op	Grain, fertilizer, soybeans	Geneva
Berne Lumber Co.	Lumber	Berne
Berne Coal and Supply Co.	Coal	Berne
Economy Printing Concern	Paper	Berne
McIntosh of Berne	Metal bins	Berne
Berne Furniture Co.	Foam rubber	Berne
Riverside, Inc.	Fertilizer	Berne
Lehman Feed Mill	Grain	Berne
Automatic Sprinkler Corp.	Steel pipe	Monroe
Sohigro, Inc.	Fertilizer	Monroe
Monroe Grain and Supply Co.	Grain	Monroe
Adams Co. Farm Bureau Co-op Elevator	Grain, fertilizer, lumber	Monroe

Table 8. Railroad Users Interviewed Along USRA Line No. 589-590

Railroad User	Major Commodity Shipped Via the Railroad	Location of User
True Temper Corp.	Wooden billets and dowels	North Vernon
Beldings, Inc.	Lumber	North Vernon
Jennings Industries	Wooden porch swings	Vernon
U.S. Army Jefferson Proving Grounds	Military equipment, ammunition	Wirt
Lichlyter Building Supply	Lumber	Madison
Charter Chemicals	Liquid chemicals	Madison
I. Weinberg, Inc.	Scrap metal	Madison
Ind.-Ky. Elec. Corp. Clifty Creek Plant	Heavy equipment	Madison
Madison River Terminal	Fertilizer	Madison
Madison State Hospital	Coal	Madison
Dover Corp.-Rotary Lift Division	Steel pipe and plates	Madison
Williamson Co.	Steel tanks	Madison
Robus Products	Scrap leather	Madison
Rexnord, Inc.	Heavy construction equipment	Madison
Barber Grocery Co.	Assorted foods	Madison

used for recording each interviewee's responses is included in Appendix F. The remainder of this chapter discusses the results from the thirty-three on-site interviews conducted by this research project.

Questions on Business and Transportation Alternatives

The initial part of the interview consisted of recording basic data related to the firm being visited. The section's final question, pertaining to the nature of the interviewee's business activities, served simply as one means of confirming the information previously obtained from other sources.

The importance of the first two questions in the interview's second section "Impact" cannot be overstated. The purpose of the first question was to determine the number of shippers who had considered the possibility of changes in rail service and the type of subsequent actions which might be taken by their firms. The following tabulation indicates the answers to this question:

Question II-A

Have possible changes in rail service caused you to explore business alternatives?

	Line No. 429	Line No. 589-590	Total
Yes	11	6	17
No	0	2	2
Had discontinued rail utilization prior to 1973	4	1	5
Have discontinued rail utilization since 1973	3	6	9
Total	18	15	33

As the above results indicate, nearly 90 percent of the firms currently shipping by rail have given thought to what actions might be taken by their companies if changes in rail service do occur. This is an indication of the seriousness of the situation in the minds of the current rail users. A significant result observed from this question's responses involves the percentage of shippers interviewed who have already ceased using rail transportation. Fifteen percent of the firms visited no longer used the railroad in 1973 while 27 percent have shifted from the rail mode since that year. Thus, nearly 42 percent of the firms interviewed are no longer rail users in 1975.

From discussions with the rail users who had ceased rail operations since 1973, it was learned that 67 percent had stopped using rail transportation for reasons other than ones directly related to the mode itself. New markets, new suppliers, and changing products often create the need for a different mode of freight transportation. In other words, normal business and marketing operations of these six companies had removed the need for railroad service. This is an important point because it indicates how the demand for a particular freight mode can fluctuate independently of any policy changes generally regarded as being under the control of the mode itself. However, it is also equally likely that firms which had previously never required rail service may begin to need the mode with the development of a new product line. A shipper thus desires the availability of two or more modes of transportation as a means of remaining competitive with other firms and of protecting investments in plant facilities.

In order to identify the types of business alternatives being considered by the 1975 rail users, the second question was included in the interview. The following tabulation contains only those responses from the shippers presently moving commodities via the railroad:

Question II-B

What alternative business action would you take if rail service was discontinued?

	Line No. 429	Line No. 589-590	Total
Go out of business	1	1	2
Reduce business size and/or employment	0	1	1
Relocate on a viable rail line	0	0	0
Switch to trucks exclusively	3	2	5
Truck to/from closest rail point	7	1	8
Other	0	1	1
Total	11	6	17

As shown by the preceding results, a similar percentage of rail users along each of the study lines would shift exclusively to motor carrier transportation with the elimination of rail service to their firms. On the other hand, there appeared to be a variation in support between the two lines for the alternative of transporting commodities by truck to the nearest rail point for subsequent, long-distance rail movement. While 64 percent of the interviewees continuing to use Line Number 429 favored this alternative, only one shipper, representing 17 percent of the interviewees presently using the North Vernon to Madison rail segment, would take a similar action. One reason partly responsible for the difference in support of the transshipping alternative might involve the lack of

adequate highway accessibility to nearby rail points in Jennings, Jefferson, and Scott counties. This deficiency appeared to discourage shippers situated along Line Numbers 589 and 590 from giving serious consideration to the alternative of transshipping. Conversely, U. S. Highway 27 in Adams and Jay counties provides direct access for companies in Bryant, Geneva, Berne, and Monroe to two nearby cities retaining rail service, Decatur and Portland.

As a means of determining which freight transportation modes, if any, were currently being used by shippers who had ceased rail patronage after 1973, the second question was also asked when ex-rail users were visited. The alternative shipping patterns discussed in the interviews would indicate those highways and bridges already in the process of assuming additional truck traffic. Furthermore, this information proved to be valuable later during the impact analysis phase of the project when the diverted rail traffic was distributed to the various highways within a study area. The question's responses when asked of past rail users are shown below:

Question II-B

What alternative business actions have been taken since discontinuing utilization of the railroad?

	Line No. 429	Line No. 589-590	Total
Have gone out of business	0	1	1
Switched to trucks exclusively	2	2	4
Currently truck to/from the closest rail point	1	1	2
Other	0	2	2
Total	3	6	9

Forty-four percent of the shippers no longer requiring rail service have switched to transporting their goods by motor carrier. When asked for reasons why trucks were being used rather than the railroad, the following comments were heard:

1. In several cases, the service provided by company trucks was regarded as being far superior to the service received from the railroad. Shippers commented on the shorter delivery times and greater reliability of trucks. The costs incurred from using company truck transportation were felt to be only slightly higher than rail costs.
2. Market changes and plant expansion sometimes removed a firm's need for shipping certain manufacturered goods via the railroad. For example, when one firm's contract for supplying a product requiring rail transportation was completed, the company's need for rail service also ended because all other products were shipped in trucks.
3. One business, by using the same trucks for transporting two separate commodities to and from the same location, has reduced transportation costs and improved delivery times by being able to provide a backhaul for its trucks. The commodity now serving as the truck's return load was shipped by rail in 1973.

Summary Comments on the Business Alternative Questions

The project's analysis of the information gathered from the railroad user interviews conducted along the Decatur to Portland and North Vernon to

Madison rail segments revealed several interesting observations considered to be deserving of special mention. Four of these points, drawn from the comments and actions of the shippers located along these two lines, are discussed in the following paragraphs.

As shown by the responses to Question II-A, a movement away from railroad utilization and toward motor carrier transportation has already occurred along each of the rail lines. Of the thirty-three shippers visited, only 58 percent were continuing to use rail service in 1975. This shift away from the railroad and toward trucks cannot be attributed entirely to certain aspects or conditions related to the rail mode itself. Everyday business operations were found to play a major role in altering a firm's demand for a particular transportation mode.

The second point, a somewhat surprising one, uncovered in the interviews involves several companies' current use of motor carrier transportation for long-distance hauling of products. This observation appears contrary to the popular belief that the only alternative to long-distance rail transportation available to a firm about to lose rail service consists of shipping by a truck/rail combination. Several shippers visited indicated that their firms were either already in the process or would give strong consideration to trucking commodities to such faraway locations as Oregon, Pennsylvania, southern Kentucky, and the New England States.

The change in grain shipping patterns which had occurred in Adams and Jay counties during the last five years deserves special discussion. From conversations with elevator operators and feed mill owners located along Line Number 429, a noticeable change in the methods of moving grain to the market was

discernable. Trucks are currently being used to transport grain from the local elevator to larger, nearby terminal facilities served by rail. Furthermore, some local elevators use motor carriers for hauling grain to distant points served by water transportation, such as, Toledo and Cincinnati, Ohio. Line Number 429 is no longer used for moving grain from the elevators situated in Bryant, Geneva, Berne, and Monroe; moreover, a future return to rail shipping of grain from these communities does not appear likely.

The final interesting point drawn from the interviewees' responses deals with the importance placed upon rail service retention on Line Numbers 429 and 589-590 by the users themselves. Comments related to this topic varied widely among the persons visited along the two lines. Two firms stated their present intentions to go out of business if rail service is eliminated to their companies. Other businesses would be forced to use less satisfactory methods of freight transportation, resulting in higher costs to their firms. On the other hand, many shippers located along the two lines have already made the switch from rail to trucking, and the shift appears to have been successful. In order to become economically viable rail lines once again, both light-density segments must recapture patronage in communities where trucking is increasing in importance. The question which arises involves whether firms who no longer use a rail facility will return to it upon the implementation of service improvements and track upgrading under state subsidization. The answer to this question holds the key to future maintenance of service on rail lines 429 and 589-590.

Questions Pertaining to Alternative Highways and Bridges

The purpose of Questions II-C, II-D, and II-E was to obtain information on which highway and street sections, including bridges, would assume the increased truck traffic diverted from the abandoned rail lines. Both present and former rail users were asked to identify the highways which would be directly affected by the closing of the two case study segments. Each interviewee was also asked to specify any known adverse conditions existing on the affected roads which could possibly prevent the accommodation of additional or heavier truck loads. Realizing that any response to Question II-E consisted of an interviewee's subjective perception of the problem, it was asked in hope that a company official might have learned of a specific adverse condition from conversations with truck drivers and other personnel.

Both current and former rail shippers were asked to comment on the following two questions:

Question II-C

> If trucking is an alternative to discontinued rail service, what major routes or highways (Interstate, U.S., or State routes) would be used for shipping products or receiving goods?

Question II-D

> If trucking is an alternative to discontinued rail service, what local roads (County roads or City streets) would be most used in reaching the nearest major routes, mentioned previously in Question II-C, for shipping products and receiving goods?

Each of the eighteen shippers visited along Line Number 429 regarded U. S. Highway 27 as the facility on which the impact of abandonment would be the greatest. As mentioned previously, a decrease in rail traffic has occurred on this branch line since 1973 with the majority of this traffic being diverted to U. S. Highway 27. The major reason for this facility being cited most often is that the highway serves as the major north-south route in the area and parallels the railroad closely for the twenty-seven miles between Decatur and Portland. Two other highways in Adams and Jay counties receiving comment included State Highways 67 and 124. However, the impact of railroad abandonment on these two facilities is expected to be minimal because each was mentioned by only two or three shippers.

From discussions with the fifteen shippers located along Line Numbers 589 and 590, several highways seem likely to be affected by the elimination of rail service to the towns of North Vernon, Vernon, Wirt, and Madison. The three highways cited most often include State Highway 7, U. S. Highway 421, and State Highway 56.

If rail service along Line Number 589 was discontinued, State Highway 7 was listed as the route likely to be used by shippers in Wirt and Madison for trucking commodities to the Baltimore and Ohio team tracks in North Vernon for subsequent, long-distance rail movement. This highway also serves as a connection for these communities to Indianapolis and points west of Indiana's capital.

A second highway apt to be traveled by trucks transporting diverted rail commodities is the segment of U. S. Highway 421 from Madison to Greensburg, Indiana. Several of Madison's shippers who are

transporting goods to or from the northeastern section of the United States named this facility when asked about trucking alternatives to direct rail service. This highway was mentioned primarily because it intersects with Interstate 74 in Greensburg.

A third highway referred to as being an important route by Madison-based shippers involves a segment of State Highway 56 from Madison to Scottsburg, Indiana. This facility was specified as being notable for two reasons. First, the route serves as a connection for Madison's firms to Blocher, Indiana which is situated on the Baltimore and Ohio rail line from Louisville, Kentucky to North Vernon. Blocher is the closest rail point retaining service which is available to Madison-based shippers. Second, State Highway 56 serves as the most direct access to Interstate 65 from Madison. From the highway's junction with Interstate 65 in Scottsburg, motor carriers may travel either north to Indianapolis or south to Louisville.

As a means of discovering any adverse conditions which might exist on the highway sections previously cited, each interviewee was asked for his comments on the following question:

Question II-E

> Please specify any adverse road, street, or bridge conditions that would be encountered in using trucking as an alternative to discontinued rail service. (Conditions such as inadequate traffic capacity, road alignment, or road width; low clearances under bridges or low load limits on bridges; poor pavement or drainage characteristics).

The responses to this question from those shippers interviewed along Line Number 429 included no mention of any adverse conditions on U. S. Highway 27.

No problems were mentioned by the users with regard to the design or performance of this highway, including its bridges. Complete confidence was expressed in this facility's ability to accommodate the additional loads being diverted from the Decatur to Portland branch line.

The rail patrons visited in the communities of North Vernon, Vernon, Wirt, and Madison voiced stronger opinions on the ability of State Highways 7 and 56 to assume the additional trucks resulting from railroad abandonment. In general, the most concern was expressed by those firms who would be forced to truck extremely heavy, oversized loads if service along Line Numbers 589 and 590 was terminated. The highway condition which was mentioned most frequently by the interviewees involved the narrow widths and the low load limits characteristic of several bridges located along both State Highways 7 and 56. One bridge on State Highway 7 in Vernon was specified as having a clearance too low for handling trucks forced to carry large, bulky equipment now being moved by the railroad. The bridge crossing the Muscatatuck River south of Vernon was also cited as being inadequate by several persons. This structure's primary deficiency is its narrow roadway width of only twenty-two feet.

A situation similar to the one existing on State Highway 7 also prevails along State Highway 56. Several Madison-based shippers were critical of the bridges located on this highway facility, in particular, the structures spanning Clifty and Crooked Creeks. The same deficiencies of inadequate widths and low load limits were mentioned frequently by the interviewees. One shipper commented that current bridge conditions along State Highway 56 were essentially limiting the amount of payload which could be transported by his firm's trucks.

In addition to the bridge inadequacies already discussed, several users voiced concern over the structural ability of the pavements of State Highways 7 and 56 to withstand the extremely heavy loads which would be diverted from rail lines 589 and 590. The rail users were then asked to comment on the nature of their commodities shipped and received in order to obtain some idea of the suitability of these payloads to truck transportation.

Questions Related to Rail Freight Characteristics

Certain commodities lend themselves well to a particular means of freight transportation. Moreover, problems may arise when these commodities are forced to be shipped by an alternative mode of transportation for which they are not especially well-suited. Questions II-F and II-G were included in the interview in order to reveal any characteristics of current rail commodities which could create problems when they are forced to be moved by an alternative means of freight transportation. Each person visited was asked the following two questions:

Question II-F

> Do you ship or receive materials (or commodities) that by their nature (dimensions, density, etc.) are highly restrictive to rail transportation?

Question II-F

> Do you know of any federal, state, or local regulations and/or labor relations restrictions which regulate the mode of transporting any commodity shipped or received?

There appeared to be no cases among the shippers interviewed along Line Number 429 in which the materials being transported by a firm were restricted solely to railroad transportation. Any commodity presently being shipped in a rail car along this line could be shifted to a truck without considerable problems. One type of rail car currently being used by a Geneva food processing plant has a special design which facilitates the loading and unloading of canned goods. Nevertheless, these canned goods, if necessary, may also be transported by motor carriers.

Question II-F drew a number of comments from current railroad patrons in Madison. These shippers are confronted with a variety of problems in any attempts to move their inbound and outbound commodities by any transportation mode other than the railroad. In particular, four of Madison's rail users - I. Weinberg, Inc., U. S. Army Jefferson Proving Grounds, Clifty Creek Power Plant, and Rexnord Inc. - move commodities which they regard as being restricted to rail transportation. The following paragraphs discuss the reasons underlying each firm's dependence on rail freight transportation.

Jerry Weinberg, the president of I. Weinberg, Inc., strongly asserted his company's need for service continuation by the railroad. The company, a dealer in scrap metal and new steel plates, demands rail access because most steel mills will purchase only scrap metal shipped to the mill via the railroad. The reason underlying this restriction is that the steel mills have installed special unloading equipment capable of handling the large volumes transported in rail cars. Therefore, trucking is not an acceptable alternative for the firm since steel mills would not buy the scrap metal hauled to them by truck.

The three remaining rail users of those listed above utilize Line Numbers 589 and 590 for moving the heavy, oversized loads demanded by their business operations. The first, Clifty Creek Power Plant of the Indiana-Kentucky Electric Corporation, transports via the railroad large pieces of equipment which demand repair or replacement. Because the weight of this equipment can range from seventeen tons to over two hundred tons apiece, the plant does not view trucking as being a viable transportation alternative. Nevertheless, these oversized shipments from Clifty Creek Power Plant are highly irregular and may occur infrequently during the year.

Jefferson Proving Grounds, operated by the United States Army as a military testing reserve, currently utilizes Line Number 589 for transporting the large pieces of military equipment operated on a trial basis at the site. The weight of the M-16 military tank often tested at the Grounds exceeds forty-eight tons, and the width of the vehicle causes it to be oversized even by rail car standards. Military cranes, brought to Jefferson Proving Grounds for frequent tests, were also regarded by military personnel as exceeding the height, width, and weight regulations that govern what types of goods may be moved by trucks.

The third Madison-based shipper, Rexnord, Inc., manufactures construction equipment and is dependent upon the railroad for moving its finished products to its customers. Although the company does ship some equipment by truck directly to nearby construction jobsites, it relies upon rail transportation for long-distance shipments. Rexnord Inc., sharing the view held by Clifty Creek Power Plant and Jefferson Proving Grounds, does not consider trucking to be a viable

alternative because of the oversized nature of its shipments and the prohibitive costs of utilizing truck/rail combinations.

The purpose of Question II-G was to determine the existence of any governmental or labor regulations which limit a shipper's modal choice when deciding on how a particular commodity should be moved. The only regulation specified by any of the users concerned the necessity of a firm's acquiring a special permit from the proper state agency when moving overweight, oversized loads via highway transportation. The extra cost involved in purchasing the permit and in providing flag car assistance was mentioned by several users who would be restricted to trucking large loads when rail service to their firms is discontinued.

Questions on Rail Shipping Data

The information gathered from Question II-H, the final question in the section "Impact", served simply as another indication of the trend away from railroad utilization and toward increasing use of motor carriers. This question was included in the interview in order to reveal any changes in rail traffic levels which might have occurred on either of the two lines since 1973. However, it had been learned from the responses to Question II-A that 27 percent of the shippers interviewed had completely ceased rail utilization since 1973 while 15 percent had discontinued rail shipments prior to that year. The following table displays the results of Question II-H when 1975 rail patrons were asked to comment on their possibilities of traffic growth or decline:

Question II-H

Many shippers anticipate changes in rail shipments in 1975-76 as a result of new markets, new facilities, new products, and new suppliers. Will your total rail shipments change substantially in 1975-76 from the 1973 level of activity?

	Line No. 429	Line No. 589-590	Total
Increase	2	0	2
Decrease	1	2	3
Remain unchanged	8	6	14
Total	11	8	19

Nearly 74 percent of the current rail users surveyed could foresee no significant change in their 1975-76 traffic levels from the 1973 levels of rail activity. Three patrons, representing 16 percent of those interviewed, anticipate decreases in rail shipments for this year. Each of the three firms experiencing decreasing rail shipments attributed his decline to the poor service and unreliable delivery times which are presently being provided by the Penn Central Transportation Company.

Only two firms, both situated on Line Number 429, expressed a hope of being able to increase the number of rail cars shipped or received at their respective businesses. The Geneva canning plant of Naas Foods, Inc. anticipates a 15 percent increase in company activity each year; therefore, the plant also expects an accompanying increase in rail shipments. The second firm, Economy Printing Concern located in Berne, anticipates an increase in rail activity from forty-five rail cars in 1973 to approximately sixty or seventy cars in 1975. Moreover, it was learned that the firm expects to increase its annual number of inbound shipments of paper to nearly one hundred rail cars within a few years.

The data collected in the interview's final section, "Rail Shipping Information", was used primarily to supplement the rail shipping data obtained from the Penn Central Traffic Tapes located at Indiana University's Center of Urban and Regional Analysis. During an interview the shipper generally provided his "best" estimate of the firm's 1973 level of rail activity. However, when comparing some of the shippers' estimates with the Penn Central data, several discrepancies between the two sources were immediately noticed. Thus, the decision was made to utilize the Penn Central data as the primary source of rail shipping information because of the uncertainty inherent in the traffic figures gathered from the interviews.

Summary of Conclusions Reached From the Interviews

From the beginning, the purpose of this study's interview program was to acquire firsthand information on what business alternatives are likely to be chosen by a rail patron confronted with possible railroad abandonment. To obtain this data, a sample of thirty-three shippers located within the two study areas were visited. Based upon observations made during the interview period, conclusions are presented herein with regard to the relative impact and alternative transportation strategies posed by branch line service discontinuance.

1. People in rural Indiana are concerned about transportation from both an on-going survival-related perspective and a more future-oriented developmental perspective.

2. A significant shift from rail transportation to motor carrier utilization has already occurred within the two case study areas. Daily business operations were found to be a primary factor in altering a firm's demand for a specific transportation mode.
3. Elevator operators in Adams and Jay counties were found to value the service qualities of truck transportation above those provided by the railroads. The security of truck shipment adds a value which some operators are willing to pay for in exchange for a decrease in price received. The increase in service quality offsets a portion of the elevator's losses.
4. A popular belief is that the best alternative to direct railroad service for the shipping of liquid chemicals, bulk fertilizer, and lumber is movement by rail to a nearby community and transfer of these materials onto a truck for the short-distance portion of the length of haul. However, contrary to this belief, several firms situated along Line Numbers 429 and 589-590 indicated their use of trucks for even long-distance commodity movements.
5. Shippers in Jefferson and Jennings counties are concerned about the ability of the aging bridges located on State Highways 7 and 56 to accommodate an increase in the number of heavy vehicles which might result from railroad abandonment. The interviewees also voiced concern over the structural ability of the pavements constituting State Highways 7 and 56 to withstand the extremely heavy loads diverted from rail lines 589 and 590.

6. Several Madison-based shippers face a variety of problems in any attempts to move their incoming and outgoing commodities by a transportation mode other than the railroad. These commodities are classified as oversized, overweight loads when being transported via motor carriers, and the shipper must acquire a special permit from the state if he elects to move these products by truck.
7. The final conclusion to be presented herein deals with the loss of flexibility suffered by shippers in small towns and rural areas when railroad service along a branch line is discontinued. These shippers desire direct railroad accessibility because rail rates are fixed for certain exempt commodities while truck and barge rates may fluctuate. Nevertheless, should a light-density rail line be subsidized by the state in order to provide transportation flexibility to firms who seldom, if ever, utilize the rail facility? The resolution of this question resides with the state's decision-makers.

RESULTS OBTAINED FROM USING THE EVALUATIVE METHODOLOGY

This chapter discusses the results of using the previously developed evaluative methodology for two areas in Indiana which contain railroad lines excluded from the ConRail network. The two case studies represent working examples of both the detailed procedure for measuring railroad abandonment's impact on highway pavements and the concise approach for estimating possible effects of additional truck use on highway bridges. In addition, the procedural demonstration reveals how existing data sources, explained in Part II, are actually employed to obtain necessary information.

As stated previously, the two railroad lines selected to provide a realistic demonstration of the evaluative system are: 1) the 27.5-mile section of USRA Line Number 429 from Decatur to Portland, and 2) the 25.8-mile segment composed of USRA Line Numbers 589 and 590 located between North Vernon and Madison. In this chapter, the results obtained from employing the adopted system are presented separately for each rail line.

The first step in evaluating the impact of abandoning a branch railroad facility involves collecting data both for the rail line undergoing analysis and for local highways which will have to accommodate increased truck volumes if service along the rail line is terminated. The length of time to be employed in measuring railroad abandonment's impact on nearby highways and bridges must be established during

this initial phase. The highways likely to be affected by rail service discontinuance must be identified and then divided into appropriate study sections according to pavement type.

After these initial steps have been completed, EAL_I values can be calculated utilizing such information as ADT volumes, percentages of trucks, and 18-kip rates per 1,000 trucks. Following determination of railroad traffic on the line under study, an EAL_D value for each of the study sections can be computed. By utilizing the values of EAL_I and EAL_D in conjunction with the impact graphs or formulas, the effect on a highway pavement of abandoning a light-density branch line may be expressed in terms of additional asphaltic concrete overlay. This added thickness of flexible pavement is required in order to prevent a decline in pavement serviceability. The last step in the process of evaluating possible impact on highway pavements involves the assessment of costs incurred from increased truck use within a study area. This step is easily accomplished once a price for bituminous concrete resurfacing has been determined.

Finally, estimating possible effects on highway structures of heavier, more frequent truck passes involves collecting data on areal bridges likely to assume additional traffic and identifying those structures which appear incapable of accommodating additional loads without some bridge repair, or possibly replacement. The abandonment of a nearby rail line might hasten the physical deterioration of a structure which is already regarded as deficient by current bridge design standards.

The First Case Study - USRA Line Number 429

Obtaining Information Required for Impact Evaluation

The methodology developed by this research effort possesses basic data requirements which must be met before analysis can begin. This section describes the manner in which these requirements were met for the initial case study area composed of Adams and Jay counties - the two counties containing the 27.5-mile segment of USRA Line Number 429 from Decatur to Portland.

Line specific rail traffic information for 1973 was obtained from Penn Central Traffic Tapes located at Indiana University's Center of Urban and Regional Analysis. From consulting these Penn Central records, the following data was obtained for the communities located along Line Number 429: 1) load specific 1973 inbound and outbound rail shipments for each station, 2) weight and commodity type of each rail carload originating or terminating on Line Number 429 in 1973, and 3) origin and destination information for each rail shipment generated by the rail line in 1973. Railroad traffic data collected from the shippers themselves during the rail user survey was utilized as supplementary information to that obtained from Penn Central records. Consequently, an excellent rail traffic profile was developed for Line Number 429. Nevertheless, the highly confidential nature of this shipping data prevents this project from disclosing line specific commodity breakdowns or rail car origins and destinations.

The identification of the highway facility likely to be affected by the potential abandonment of Line Number 429 was relatively simple. U. S. Highway 27

parallels the rail line under study for its entire length from Decatur to Portland. In addition, each of the railroad interviewees in Adams and Jay counties suggested during the rail user survey that U. S. Highway 27 would be the facility forced to assume increased truck numbers. The affected highway was divided into sections based on information contained in the sufficiency ratings and road life records of the ISHC Planning Department (13). The first criterion for establishing these sections involved both the pavement type of the section and its initial year of construction; however, it became necessary to further subdivide some sections in order to make them homogeneous with respect to ADT volumes or percentages of trucks. Thus, based on the above information, U. S. Highway 27 was divided into ten principal study sections for its distance between Decatur and Portland. Table 9 contains a description and pertinent data for each of the ten analysis sections located on U. S. Highway 27.

After the study sections were delineated, an appropriate soil support value for each flexible pavement segment was ascertained by employing the soil map of Indiana, reproduced in this report as Figure 31, in conjunction with the table of soil support values developed by Ulbricht in his 1967 study, Table 25 on page 208 (25). Although it was not necessary for any of the study segments located on U. S. Highway 27 from Decatur to Portland, further subdivision of a flexible pavement section would be required if the pavement is supported by two or more soil types possessing different S-values. An S-value of 5.0 was determined for the 4 flexible pavement sections of U. S. Highway 27.

Table 9. Analysis Sections Located Along U. S. Highway 27

Section	Year Built	Length (mi.)	Type of Pavement	1973 % Trucks	1973 ADT (2-way)
1. N. city limits of Portland to 0.35 mi. S. of Bryant	1934	5.377	Rigid	6.15	6,707
2. 0.35 mi. S. of Bryant to SR 67	1929	0.946	Rigid	5.00	6,034
3. SR 67 to SR 116	1930	3.636	Rigid	5.00	4,819
4. SR 116 to Jerome Street in Berne	1930	3.490	Rigid	5.00	6,767
5. Jerome Street to SR 218	1930	0.770	Rigid	20.00	7,900
6. SR 218 to 0.22 mi. N. of Parr Road in Berne	1929	0.810	Flexible	17.43	5,827
7. 0.22 mi. N. of Parr Road to 1.0 mi. S. of SR 124	1929	4.280	Flexible	5.00	5,500
8. 1.0 mi. S. of SR 124 to 1.375 mi. N. of SR 124	1932	2.375	Flexible	5.00	5,303
9. 1.375 mi. N. of SR 124 to 0.75 mi. S. of Decatur	1938	3.496	Flexible	7.00	7,700
10. S. city limits of Decatur to Old U.S. 27 junction	1932	0.500	Rigid	20.00	10,600

Source: Based on information from the 1973 sufficiency ratings and road life records of the Indiana State Highway Commission Planning Department.

For the six rigid pavement study sections, typical values for the working stress in concrete and the modulus of subgrade reaction were assumed. The f_t-value assumed for the rigid sections was 500 psi while the assumed k-value equaled 250 psi/in.

A time span of 10 years was selected as the length of analysis period over which railroad abandonment's impact was to be measured. Since both highway and railroad data which had been previously collected were for the year 1973, it was decided that the 10-year analysis period should begin on January 1 of that year. Furthermore, because a normal increase in traffic volumes will likely occur on the 10 study sections in the future regardless of the final disposition of USRA Line Number 429, it was assumed that a 4 percent annual increase in vehicle volumes would occur throughout the 10-year analysis period. This supposition was based on traffic information taken from ISHC sufficiency ratings for U. S. Highway 27.

The final source of information consulted in the data acquisition stage was the report summarizing truck weight data collected by ISHC during 1973 (15). For this case study involving U. S. Highway 27, it was assumed that the two 18-kip rates per 1,000 for all trucks, obtained from the W-4 loadometer table for Other Main Rural (Non-Interstate) Highways (15), were applicable to the 10 pavement sections undergoing impact analysis. The 18-kip equivalency rates, one for each of the two pavement types, were used in determining EAL_I values for all study segments located between Decatur and Portland.

After the initial data gathering phase had been completed, EAL_I, EAL_H, and EAL_D values, required information for employing either the impact graphs or

the impact formulas, were calculated, and the following sections explain the results of these computations.

Determining the Three Required EAL Values

The calculation of EAL_I values for the ten study sections constituting U. S. Highway 27 was accomplished by using the AASHO simplified procedure as it was previously explained in Part II. It is in this calculation where it is important that a study section be as homogeneous as possible for the computed EAL value is highly sensitive to the two parameters affected by subsection consolidation, namely, average daily traffic and percentage of commercial vehicles. The employed 18-kip rates, as expressed in equivalent 18-kip single-axle load applications per 1,000 trucks and combinations, were: 1) 379.8 for rigid pavements, and 2) 259.1 for flexible pavements (15). Table 10 contains the 10 EAL_I values calculated by this project for U. S. Highway 27.

Following EAL_I computations for the affected sections composing U. S. Highway 27, corresponding EAL_H values were determined by using a 4 percent annual growth rate occurring throughout the 10-year analysis period. These calculations were performed by using the formula presented in Part II, and Table 10 also contains the determined EAL_H values for the 10 study sections.

The determination of EAL_D values for U. S. Highway 27 involved combining information from various sources. The rail carloads generated by USRA Line Number 429 for 1973 were determined by referring to the Penn Central Traffic Tapes. These rail carloads were converted to an equivalent volume of motor carriers by employing the techniques described in Part II entitled,

Table 10. Values of EAL_I and EAL_{II} for Analysis Sections Located Along U. S. Highway 27

Section	EAL_I for Design Lane	EAL_{II} for Design Lane
1. N. city limits of Portland to 0.35 mi. S. of Bryant	616,500	912,500
2. 0.35 mi. S. of Bryant to SR 67	500,000	740,500
3. SR 67 to SR 116	381,500	564,700
4. SR 116 to Jerome Street in Berne	548,500	811,800
5. Jerome Street to SR 218	2,600,000	3,800,000
6. SR 218 to 0.22 mi. N. of Parr Road in Berne	1,100,000	1,700,000
7. 0.22 mi. N. of Parr Road to 1.0 mi. S. of SR 124	312,000	462,000
8. 1.0 mi. S. of SR 124 to 1.375 mi. N. of SR 124	283,000	419,000
9. 1.375 mi. N. of SR 124 to 0.75 mi. S. of Decatur city limits	506,400	749,700
10. S. city limits of Decatur to Old U. S. 27 junction	3,300,000	4,900,000

"Principles and Procedures". However, since the size or configuration of each motor carrier to be used for transporting the diverted rail commodities was not precisely known, the conversion procedure was performed twice, assuming two separate truck configurations. The initial conversion procedure for Line Number 429 consisted of diverting all freight which would have been moved via the railroad between 1973 and 1983 to 5-axle tractor semi-trailer carriers having a legal gross weight of 73,280 pounds. This truck configuration is very common since it is generally used for long-distance goods movement. Each truck was assumed to be carrying the legal weight limit or less, and the tare weight of the tractor semi-trailer combination was taken to be 28,000 pounds.

The second modal shift of freight from Line Number 429 to U. S. Highway 27 involved transferring commodities formerly moved by way of rail to 4-axle tractor semi-trailer trucks which possess a legal gross weight limit of 62,000 pounds. This truck type is most often used for carrying freight from the shipper's dock to a truck terminal; thus, it could possibly be the type employed for moving commodities from a firm which loses rail service to the closest railroad. Each truck was once again assumed to be transporting the legal weight limit or less, and the tare weight of the tractor semi-trailer combination was postulated to be 26,000 pounds.

The directional distribution to U. S. Highway 27 of those truck volumes ascertained in the preceding step was based primarily on the information gathered from the shippers themselves during the railroad user interviews. Information related to the transportation alternatives available to a railroad interviewee confronted with branch line abandonment represented perhaps the most important output of the rail user

survey and was extensively employed during the truck distribution process. For those commodities which could not be easily matched to one of the interviewed railroad shippers, distribution to affected highway sections was predicated on origin and destination data obtained from Penn Central shipping records.

After all truck volumes had been assigned to U. S. Highway 27, values for EAL_D were calculated for each of the ten pavement sections according to the method introduced in Part II. For all study sections, two EAL_D values, one for each direction of vehicular travel, were calculated with the larger value for each section being used for impact analysis. A structural number of 3.0 and a concrete slab thickness of 9 inches were assumed for all conversions of motor carrier volumes to equivalent 18-kip single-axle load applications. Finally, additional load repetitions caused by both overloaded and empty motor carriers were taken into account by employing the techniques described in Chapter 3. Table 11 contains the determined truck volumes along with the corresponding EAL_D values for the 10 sections constituting U. S. Highway 27 from Decatur to Portland.

Results Obtained from Employing the Impact Graphs

Once the percentage increase in EAL had been calculated for all cases, the final step in evaluating the effect of abandoning USRA Line Number 429 on U.S. Highway 27 consisted of reading the proper impact graph, Figures 4 through 22, to determine the additional amount of bituminous concrete overlay which is needed in order to prevent a decline in a section's service life. Overlay thicknesses were determined for each of the two truck types: 1) the 5-axle tractor

Table 11. Diverted Truck Volumes and EAL_D Values for Analysis Sections Located Along U. S. Highway 27

Section	5-axle Truck		4-axle Truck	
	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)
1. N. city limits of Portland to 0.35 mi. S. of Bryant	2,790	6,230	3,280	8,124
2. 0.35 mi. S. of Bryant to SR 67	2,790	6,280	3,280	8,124
3. SR 67 to SR 116	2,660	6,260	3,120	8,108
4. SR 116 to Jerome Street in Berne	2,400	5,784	2,800	7,281
5. Jerome Street to SR 218	2,400	5,784	2,800	7,281
6. SR 218 to 0.22 mi. N. of Parr Road in Berne	6,550	9,800	7,740	15,285
7. 0.22 mi. N. of Parr Road to 1.0 mi. S. of SR 124	6,550	9,800	7,740	15,285
8. 1.0 mi. S. of SR 124 to 1.375 mi. N. of SR 124	7,220	10,589	8,520	16,363
9. 1.375 mi. N. of SR 124 to 0.75 mi. S. of Decatur city limits	7,220	10,589	8,520	16,363
10. S. city limits of Decatur to Old U.S. 27 junction	7,220	17,013	8,520	20,908

semi-trailer, and 2) the 4-axle tractor semi-trailer. The results of this step are contained in Table 12.

As shown by Table 12, discontinuing railroad service along Line Number 429 from Decatur to Portland would have practically no impact on the 10 sections' pavement structures that compose the segment of U. S. Highway 27 undergoing analysis. It appears from inspecting the table that increased truck volumes, resulting from over-the-road transportation of commodities shipped by rail prior to 1973, would not create a need for placing additional flexible overlay on U. S. Highway 27 as of the horizon year 1983. Although no increase in diverted rail freight was assumed to occur throughout the ten-year analysis period, the sheer magnitude of the overlay thicknesses computed for the no-growth case suggests that current utilization of Line Number 429 must increase considerably before significant highway impact is likely to take place.

Other Impacts of Abandoning Line Number 429

Although railroad abandonment's impact on the pavement structure of U.S. Highway 27 appears negligible, service discontinuance on Line Number 429 could have other effects which deserve consideration. With regard to traffic congestion, the greatest annual increase in truck volumes due to closure of the Decatur to Portland branch line involves about 852 4-axle motor carriers diverted to the pavement sections situated between Monroe and Decatur. However, this increase of less than three trucks per day on the average would not appear to be a serious traffic burden on these sections. On the other hand, problems might arise from the use of large tractor semi-trailer

Table 12. Increases in Required Overlay Thickness for Analysis Sections Located Along U. S. Highway 27

Section	5-axle Truck		4-axle Truck	
	Increase in EAL (%)	Δt (in.)	Increase in EAL (%)	Δt (in.)
1. N. city limits of Portland to 0.35 mi. S. of Bryant	0.69	(1)	0.89	(1)
2. 0.35 mi. S. of Bryant to SR 67	0.85	(1)	1.10	0.04
3. SR 67 to SR 116	1.11	0.04	1.44	0.05
4. SR 116 to Jerome Street	0.72	(1)	0.90	(1)
5. Jerome Street to SR 218	0.15	(1)	0.19	(1)
6. SR 218 to 0.22 mi. N. of Parr Road	0.58	(1)	0.90	(1)
7. 0.22 mi. N. of Parr Road to 1.0 mi. S. of SR 124	2.13	0.02	3.31	0.03
8. 1.0 mi. S. of SR 124 to 1.375 mi. N. of SR 124	2.53	0.03	3.91	0.04
9. 1.375 mi. N. of SR 124 to 0.75 mi. S. of Decatur city limits	1.41	0.02	2.18	0.02
10. S. city limits of Decatur to Old U. S. 27 junction	0.35	(1)	0.43	(1)

[1]Less than 0.01.

carriers for transporting commodities to both Berne Coal and Supply Company and Economy Printing Concern, two principal shippers in Berne. These motor carriers may add to congestion on major city streets of Berne since the two firms are located in the downtown business area.

A second impact of abandoning Line Number 429 deals with the economic costs which must be borne by the shippers, and ultimately the consumers of the products presently sent by rail to and from the communities of Bryant, Berne, Geneva, and Monroe. Several shippers located along the Decatur to Portland branch line will face increased transport costs if they are forced to shift from rail to truck transportation. Although this project did not attempt quantification of these costs for the affected railroad users, this aspect should be considered during any branch line analysis.

The effect of the abandonment of Line Number 429 on the six bridges located on the study sections of U. S. Highway 27 was observed to be negligible at the present time. None of the six structures are included on either the list of one hundred Indiana bridges in most need of replacement or the list of two hundred structures in greatest need of repair. However, this current situation of structural adequacy could change over the ten-year analysis period as more and more heavily-loaded trucks utilize the six highway structures situated on U. S. Highway 27.

The Second Case Study - USRA Line Numbers 589 and 590

Obtaining Information Required for Impact Evaluation

The process for procuring data required for evaluating the impact of closing the North Vernon to Madison branch line was essentially the same as the procedure described previously for USRA Line Number 429. Line specific railroad shipping data was again obtained from the Penn Central Traffic Tapes; thus, an accurate rail traffic profile was generated for Line Numbers 589 and 590.

The delineation of those highways in the 3-county study area which might be affected by railroad abandonment was accomplished primarily by using the results of the rail user survey conducted by this research effort. As stated previously in Chapter II, the 15 railroad interviewees located in the communities of North Vernon, Vernon, Wirt, and Madison had generally mentioned 3 highways on which rail service discontinuance would most likely have an impact: 1) State Highway 7, 2) State Highway 56, and 3) U. S. Highway 421. Because the first two facilities were designated by the rail users more often than the third, State Highways 7 and 56 were chosen to be working examples of the developed methodology.

The two aforementioned highways were divided into appropriate study sections by employing the same criteria explained previously for U. S. Highway 27. The portion of State Highway 7 from North Vernon to Madison was separated into 4 analysis segments while the portion of State Highway 56 located between Madison and Scottsburg was divided into 8 separate sections. Tables 13 and 14 contain descriptions and pertinent data for the 12 analysis sections constituting the two highways.

Table 13. Analysis Sections Located Along State Highway 7

Section	Year Built	Length (mi.)	Type of Pavement	1973 % Trucks	1973 ADT (2-way)
1. S. city limits of North Vernon to SR 3	1931	1.190	Rigid	6.72	8,717
2. SR 3 to Co. Rd. 26	1931	15.140	Rigid	3.18	2,540
3. Co. Rd. 26 to Co. Rd. 259	1937	2.660	Flexible	5.00	4,400
4. Co. Rd. 259 to Fayette Street in Madison	1937	2.440	Flexible	13.51	4,800

Source: Based on information from the 1973 sufficiency ratings and road life records of the Indiana State Highway Commission Planning Department.

Table 14. Analysis Sections Located Along State Highway 56

Section	Year Built	Length (mi.)	Type of Pavement	1973 % Trucks	1973 ADT (2-way)
1. Madison city limits to 0.94 mi. W. of city limits	1937	0.940	Flexible	7.85	8,185
2. 0.94 mi. W. of Madison city limits to SR 107	1932	1.760	Rigid	7.00	7,988
3. SR 107 to Madison Avenue in Hanover	1932	1.540	Rigid	7.00	10,000
4. Madison Avenue to SR 62	1932	3.520	Rigid	5.00	5,877
5. SR 62 to N. Jct. of SR 3	1932	9.080	Rigid	3.00	1,571
6. N. Jct. of SR 3 to W. Jct. of SR 203	1937	4.070	Flexible	3.00	2,683
7. W. Jct. of SR 203 to 0.13 mi. E. of Fifth Street	1937	2.850	Flexible	5.00	3,900
8. 0.13 mi. E. of Fifth Street to E. city limits of Scottsburg	1938	0.270	Flexible	15.00	5,300

Source: Based on information from the 1973 sufficiency ratings and road life records of the Indiana State Highway Commission Planning Department.

Soil support values for the 6 flexible pavement sections, 2 situated on State Highway 7 and 4 located along State Highway 56, were determined from the results of Ulbricht's 1967 study (25). The predominant soil type in Jefferson, Jennings, and Scott counties is the soil unit, "old drift, silts, and silty clays"; thus, an S-value of 5.0 was applicable to the majority of flexible sections. One exception involved an analysis segment located near Scottsburg which is constructed on the soil unit "lakebeds". This section was assigned an S-value of 4.0.

With regard to the six rigid pavement study segments, values for the working stress in concrete and the modulus of subgrade reaction were assumed to be 500 psi and 250 psi/in., respectively. These two values are regarded as being characteristic of highways located within Indiana.

In the same manner as the first case study, the length of analysis period was assumed as ten years starting from January 1, 1973. Similar to U. S. Highway 27, a 4 percent normal increase in traffic per year was postulated to occur during the entire analysis period for the two highways undergoing evaluation. This supposition was predicated once more on traffic volume data contained in the sufficiency ratings for State Highways 7 and 56.

The 18-kip equivalency rates which were used in calculating EAL_I vaues for the 12 study segments composing States Highways 7 and 56 were again the 2 rates per 1,000 trucks obtained from the W-4 loadometer table for the highway classification, Other Main Rural (Non-Interstate) Highways (15). Both of the affected facilities belong to this particular highway classification; hence, the aforementioned 18-kip equivalency rates were considered pertinent to this case study.

Following completion of the initial data collection phase for the three-county study region, EAL_I, EAL_H, and EAL_D values were determined, and the succeeding sections discuss the results of these computations.

Determining the Three Required EAL Values

The AASHO simplified method for the calculation of 18-kip equivalent single-axle loads was employed to ascertain EAL_I values for the 12 study segments of State Highways 7 and 56. The same 18-kip equivalency rates, 379.8 for rigid pavements and 259.1 for flexible pavements, were used in these EAL_I computations as had been used previously in the case of U. S. Highway 27 (15). The 12 EAL_I values calculated by this research effort for State Highways 7 and 56 are included in Table 15.

Subsequent to the required EAL_I calculations, corresponding EAL_H values were determined from using the growth formula introduced in Chapter 7 of Part II. For these calculations, it was assumed that a 4 percent annual growth in traffic would occur throughout the 10-year analysis period. Table 15 also contains the EAL_H values for each of the 12 study sections.

The determination of the number of equivalent 18-kip single-axle load applications diverted from USRA Line Numbers 589 and 590 between 1973 and 1983 was accomplished in a manner similar to that described previously for the first case study, USRA Line Number 429. Two separate truck configurations were again assumed to be transporting the commodities which would have been moved by rail if the North Vernon to Madison rail line had not been hypothetically closed for purposes of this study on January 1, 1973. The first truck type, the 5-axle tractor semi-trailer, was postulated as carrying its legal gross weight of

Table 15. Values of EAL_I and EAL_H for Analysis Sections Located Along State Highways 7 and 56

Section	EAL_I for Design Lane	EAL_H for Design Lane
State Highway 7		
1. S. city limits of North Vernon to SR 3	931,500	1,400,000
2. SR 3 to Co. Rd. 26	128,000	190,000
3. Co. Rd. 26 to Co. Rd. 259	211,000	312,500
4. Co. Rd. 259 to Fayette Street in Madison	623,000	922,300
State Highway 56		
1. Madison city limits to 0.94 mi. W. of city limits	616,200	912,200
2. 0.94 mi. W. of Madison city limits to SR 107	869,600	1,300,000
3. SR 107 to Madison Ave. in Hanover	1,100,000	1,600,000
4. Madison Avenue to SR 62	460,400	681,500
5. SR 62 to N. Jct. of SR 3	74,000	109,400
6. N. Jct. of SR 3 to W. Jct. of SR 203	78,300	116,000
7. W. Jct. of SR 203 to 0.13 mi. E. of Fifth Street	187,200	277,200
8. 0.13 mi. E. of Fifth Street to E. city limits of Scottsburg	744,800	1,100,000

73,280 pounds or less while the second motor carrier type, the 4-axle tractor semi-trailer, was assumed to be transporting 62,000 pounds or less.

The directional distribution to the local highway system of the truck volumes calculated in the preceding step was more complex for this case study than for the first simply because more highways in this three-county area possess the probability of being used for over-the-road transportation of diverted rail freight. The distribution process was predicated largely on the opinions of the shippers themselves acquired during the rail user survey. However, when distributing those commodities which could not be attributed to one of the interviewed railroad users, it became necessary to route goods on the basis of 1973 Penn Central origin and destination data.

Following the assignment of determined truck volumes to the highway system of Jennings, Jefferson, and Scott counties, EAL_D values were computed for the affected sections of State Highways 7 and 56. For each of the 12 sections, either a structural number of 3.0 or a concrete slab thickness of 9 inches was assumed for converting volumes of motor carriers to equivalent 18-kip single-axle loads. Furthermore, EAL values resulting from both overloaded and empty trucks were included in the determination of EAL_D by utilizing the procedures explained in Part II. Tables 16 and 17 list the determined truck volumes together with corresponding EAL_D values for the 12 study sections of State Highways 7 and 56.

Table 16. Diverted Truck Volumes and EAL_D Values for Analysis Sections Located Along State Highway 7

Section	5-axle Truck		4-axle Truck	
	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)
1. S. city limits of North Vernon to SR 3	7,330	12,400	10,270	19,338
2. SR 3 to Co. Rd. 26	6,680	12,287	9,630	19,245
3. Co. Rd. 26 to Co. Rd. 259	6,250	6,539	9,240	13,430
4. Co. Rd. 259 to Fayette Street in Madison	11,190	10,710	14,650	18,151

Table 17. Diverted Truck Volumes and EAL_D Values for Analysis Sections Located Along State Highway 56

Section	5-axle Truck		4-axle Truck	
	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)	Diverted Truck Traffic (10-yr.)	EAL_D for Design Lane (10-yr.)
1. Madison city limits to 0.94 mi. W. of city limits	11,620	14,288	13,100	23,450
2. 0.94 mi. W. of Madison city limits to SR 107	11,620	22,409	13,100	29,184
3. SR 107 to Madison Avenue in Hanover	11,620	22,409	13,100	29,184
4. Madison Avenue to SR 62	11,620	22,409	13,100	29,184
5. SR 62 to N. Jct. of SR 3	11,620	22,409	13,100	29,184
6. N. Jct. of SR 3 to W. Jct. of SR 203	7,040	9,105	7,830	15,343
7. W. Jct. of SR 203 to 0.13 mi. E. of Fifth Street	7,040	9,105	7,830	15,343
8. 0.13 mi. E. of Fifth Street to E. city limits of Scottsburg	7,040	9,105	7,830	15,343

Results Obtained from Employing the Impact Graphs

After determining the percentage increase in EAL for the twenty-four cases constituting the second example of impact evaluation, the effect of discontinuing railroad service to the communities of North Vernon, Vernon, Wirt, and Madison via Line Numbers 589 and 590 was ascertained by reading the appropriate impact graph. Abandonment's impact on the pavement structures of State Highways 7 and 56, as shown by the graphs (Figures 4 through 22), is expressed in terms of additional thickness of asphaltic concrete overlay. Unless this thickness of flexible overlay is placed above the pavement structure near the end of the analysis period 1983, the highway section undergoing analysis will experience a decline in pavement serviceability - a deterioration which can be attributed entirely to the abandonment of USRA Line Numbers 589 and 590. The impact on the various study sections composing State Highways 7 and 56 is shown in Tables 18 and 19.

From inspecting Tables 18 and 19, it is possible to see how the effect of abandoning the North Vernon to Madison branch line varies for different pavement sections of State Highways 7 and 56. The impact of rail service discontinuance on these two highways ranges from being almost insignificant for some study sections to 0.60 inches of bituminous concrete resurfacing for a 9.08-mile segment of State Highway 56. For each of the 12 highway sections, freight diversion from rail cars to 4-axle tractor semi-trailers would have a greater consequence with respect to pavement serviceability than a corresponding shift of railroad freight to 5-axle tractor semi-trailer carriers. In addition, for a given EAL increase due to rail service

Table 18. Increases in Required Overlay Thickness for Analysis Sections Located Along State Highway 7

Section	5-axle Truck		4-axle Truck	
	Increase in EAL (%)	Δt (in.)	Increase in EAL (%)	Δt (in.)
1. S. city limits of North Vernon to SR 3	0.89	(1)	1.38	0.05
2. SR 3 to Co. Rd. 26	6.47	0.16	10.13	0.25
3. Co. Rd. 26 to Co. Rd. 259	2.09	0.02	4.30	0.05
4. Co. Rd. 259 to Fayette Street in Madison	1.16	0.01	1.97	0.02

[1]Less than 0.01.

Table 19. Increases in Required Overlay Thickness for Analysis Sections Located Along State Highway 56

Section	5-axle Truck		4-axle Truck	
	Increase in EAL (%)	Δt (in.)	Increase in EAL (%)	Δt (in.)
1. Madison city limits to 0.94 mi. W. of city limits	1.57	0.02	2.57	0.03
2. 0.94 mi. W. of Madison city limits to SR 107	1.73	0.06	2.25	0.10
3. SR 107 to Madison Avenue in Hanover	1.40	0.05	1.82	0.06
4. Madison Avenue to SR 62	3.29	0.12	4.29	0.15
5. SR 62 to N. Jct. of SR 3	20.49	0.50	26.68	0.60
6. N. Jct. of SR 3 to W. Jct. of SR 203	7.85	0.07	13.23	0.12
7. W. Jct. of SR 203 to 0.13 mi. E. of Fifth Street	3.29	0.03	5.54	0.05
8. 0.13 mi. E. of Fifth Street to E. city limits of Scottsburg	0.83	(1)	1.40	0.03

[1]Less than 0.01.

discontinuance, it appears that abandonment's impact will be greater on rigid pavements than on flexible pavements.

Evaluating Railroad Abandonment's Impact on Highway Structures

By utilizing information collected by the ISHC Bridge Design Department (14), an analysis was conducted on the capability of the affected bridges located along State Highways 7 and 56 to accommodate additional truck traffic due to the closing of Line Numbers 589 and 590. The following paragraphs summarize the more important results obtained from the completed analysis.

One bridge located on State Highway 7 and two structures situated on State Highway 56 are scheduled for replacement in the near future according to the current Two-Year Capital Improvements Program for the state of Indiana. The structure on State Highway 7 spans the Muscatatuck River south of Vernon and was constructed over forty-five years ago. Plans for its replacement are presently in the development stage. Both of the bridges located along State Highway 56 transverse railroad lines. The first, the structure spanning Line Number 590 west of Madison, currently has a load limit less than the maximum allowable load limit generally established for Indiana's bridges. Construction on a new bridge at this site is scheduled to begin within the next year. The second structure crosses the Baltimore and Ohio rail facility which passes through Blocher, Indiana. Plans for replacing this structure in Scott County have not yet been developed. Thus, it appears that several bridges in the three-county study area have already deteriorated to the point of requiring prompt replacement.

The bridge which spans Big Graham Creek in Jennings County, although not slated for immediate reconstruction, is included in the list of the 100 Indiana structures in greatest need of replacement. This list was compiled by the ISHC Bridge Design Department, and it contains only bridges which are located on state or federal highways. The Big Graham Creek structure, located on State Highway 7, has a roadway width of only 22 feet and a low sufficiency rating of 72 percent. Therefore, heavier, more frequent truck passes resulting from the closure of Line Numbers 589 and 590 could serve to aggravate the existing deficiencies of the Big Graham Creek structure and to hasten the need for its replacement.

Three bridges located on study sections of State Highway 7 in Jefferson County are contained in the ISHC tabulation of the 200 Indiana structures in most need of bridge repair. Although the structures crossing Hensley and Harbath's Creeks have been built within the last 15 years, both possess sufficiency ratings which are below 75 percent, one indication of a need for bridge renovation. The Big Creek bridge has an even lower sufficiency rating of 68 percent plus a narrow roadway width of only 20 feet. Furthermore, a fourth bridge located on State Highway 7 in Jefferson County, the structure transversing Middle Fork Creek, possesses a poor sufficiency rating of 61 percent although it was not cited by the ISHC as requiring either repair or replacement.

There are also 3 bridges situated on State Highway 56, 2 in Jefferson County and 1 in Scott County, which have been included in the aforementioned list of Indiana structures in need of repair. Both of the bridges which span Clifty and Big Springs Creeks west of Madison were constructed in 1931 and have a roadway

width of 24 feet. Sufficiency ratings for the 2 structures are 75 and 73 percent, respectively. The single bridge on the list from Scott County, the structure crossing Pigeon Roost Creek, has a relatively high sufficiency value of 81 percent and possesses an adequate width of 28 feet; thus, the structure must be deficient in other respects if bridge repair is demanded. A second bridge located on one of the sections of State Highway 56 in Scott County would appear to demand either repair or replacement from inspection of its assigned sufficiency rating. The Stucker Creek bridge situated just west of the junction of State Highways 3 and 56 not only is over 50 years old but has a roadway width of only 20 feet. Although this structure has been assigned a sufficiency value of 60 percent, it received no mention in either of the lists prepared by the Indiana State Highway Commission.

As discussed in the preceding paragraphs, there are numerous bridges in this 3-county study area which could be adversely affected by the abandonment of Line Numbers 589 and 590. Several structures located along both State Highway 7 and State Highway 56 have already deteriorated to the point of requiring immediate repair or replacement. Of the 10 structures situated on the North Vernon to Madison segment of State Highway 7, 5 have been specified by the ISHC as warranting prompt reconstruction or renovation. Furthermore, 2 of the other 5 bridges have been assigned sufficiency ratings of less than 75 percent and may soon be added to the lists of structures needing extensive maintenance work.

With regard to the 9 structures located along State Highway 56 from Scottsburg to Madison, 5 are apparently in need of either extensive upgrading or reconstruction according to information which has been compiled by the ISHC Bridge Design Department. Two of the other 4 have sufficiency values of less than 75 percent. Thus, 14 of the 19 structures located along State Highways 7 and 56 would appear to be extremely vulnerable to increased numbers of heavy trucks resulting from branch line abandonment. In particular, the oversize nature of several of the diverted commodities could hasten the physical deterioration of bridges which already possess structural deficiencies. Therefore, it may be concluded from the analysis that railroad abandonment's principal impact on areal bridges involves the manner in which it will intensify the physical deterioration of the deficient structures predominating along State Highways 7 and 56.

Assessing the Financial Impact of Abandoning Line Numbers 589 and 590

Although it was not possible to establish what portion of the costs associated with bridge repair or replacement should be attributed to the additional traffic resulting from branch line abandonment, it was feasible to determine the additional amount of money which must be spent for pavement resurfacing. The cost figures developed by this research effort concerning highway resurfacing were based on 1973 bid prices taken from the Catalog of U.P.A. Prices for Roads and Bridges, a document prepared by the Special Provisions Group of the Indiana State Highway Commission (12). The following paragraphs discuss the financial impact on State Highways 7 and 56 of

discontinuing railroad service along the North Vernon to Madison branch line.

Costs related to highway repaving were determined for 2 sections of State Highways 7 and 56 on which abandonment's impact was estimated to be relatively significant. The 2 study segments are: 1) the 9.08-mile section of State Highway 56 between the junction of State Highway 62 and the north junction of State Highway 3, and 2) the 15.14-mile portion of State Highway 7 from its junction with State Highway 3 to County Road 26. As shown by Tables 18 and 19, the first highway segment will require an asphaltic concrete overlay of 0.60 inches while the latter section will demand a thickness of 0.25 inches. This extra overlay thickness is in addition to the normal overlay thickness which would be required even if the traffic due to rail freight diversion was not considered. For the section of State Highway 56, the abandonment of Line Numbers 589 and 590 resulted in an increase of $82,600 to the resurfacing cost that would be required under normal conditions. The corresponding increase for the segment of State Highway 7 was computed to be $62,600.

The results of the cost analysis conducted by this research project are contained in Table 20. These expenditures are predicated on a price of $23.50 per ton of asphaltic concrete resurfacing which represents the average bid price for this paving material in Indiana during 1973.

In summary, it is emphasized that the fiscal outlays contained in Table 20 do not encompass all the additional costs incurred along State Highways 7 and 56 which are related to the abandonment of Line Numbers 589 and 590. Annual maintenance costs for the sections composing the two highways undergoing

Table 20. Resurfacing Costs Resulting from the Abandonment of USRA Line No. 589 and 590

Section	Added Costs due to Rail Freight Diversion
State Highway 7	
1. 9.08-mile segment from SR 62 to N. Jct. of SR 3	$82,600
State Highway 56	
2. 15.14-mile segment from SR 3 to Co. Rd. 26	$62,600

analysis could increase considerably due to additional truck use, but these expenditures are difficult to measure. As stated previously, bridge repair and replacement costs resulting from heavier, more frequent truck passes also cannot be quantified. Therefore, the figures presented in Table 20 are useful for purposes of providing a first approximation of the financial impact on local highways of abandoning the North Vernon to Madison branch line.

Other Impacts of Abandoning Line Numbers 589 and 590

The discontinuance of railroad service to the communities located along the North Vernon to Madison branch line would not appear to create any major problems on State Highways 7 and 56 with regard to traffic congestion. The largest annual diversion of motor carriers to either of the two highways being studied is about 1,465 4-axle tractor semi-trailers which would be used for transporting goods on the sections of State Highway 7 between North Madison and Madison. Although an average daily increase in truck traffic of only four motor carriers seems insignificant, any increase in truck numbers on this segment of State Highway 7 should be noted. The portion of State Highway 7 from North Madison to Madison contains extremely sharp curves and steep grades. Large trucks are forced to travel at low speeds due to the highway's extreme geometric characteristics; the major result is traffic congestion as following vehicles are unable to pass the slow-moving trucks. Thus, an increase, on the average, of four large, slow-moving vehicles per day on a two-lane highway facility possessing low-quality geometric design standards is more serious

than it would first appear, particularly when considering traffic safety. Furthermore, the diversion of additional tractor semi-trailers to major city streets of Madison and Hanover represents another consideration related to traffic congestion and highway safety.

Similar to the situation existing in the first case study, one effect of the elimination of railroad service to this three-county region involves the economic costs which must be borne by the affected shippers. Several Madison-based companies indicated a need for railroad service to remain competitive with companies similar to their own in other parts of the State and nation. This economic impact of abandoning Line Numbers 589 and 590 was not quantified by this research effort; however, it is an important aspect of railroad abandonment which deserves serious consideration.

Conclusions Reached from Employing the Methodology for the Two Case Studies

By employing the methodology developed in this study, possible effects of railroad service discontinuance on local highways were measured for two areas within the state of Indiana. The two case studies served as working examples of the procedure that shipper groups, local communities, or state governmental agencies can follow in estimating railroad abandonment's highway impact. Based on the results of the impact evaluations conducted by this research effort, conclusions are presented herein with regard to the relative impact on rural highways that is likely to result from the abandonment of USRA Line Number 429 or USRA Line Numbers 589 and 590.

1. The structural strength of the pavement of U. S. Highway 27, a parallel highway to Line Number 429, was observed to be sufficient to accommodate the additional truck traffic due to the diversion of commodities which would have been moved via the railroad during the period 1973 to 1983. Although it was assumed that no growth in rail car traffic would take place along the Decatur to Portland branch line between 1973 and 1983, the magnitude of the extra pavement thicknesses associated with the no-growth case appears to indicate that a large growth in shipping on Line Number 429 would have to occur before significant impact on U. S. Highway 27 is likely to result. Nevertheless, yearly maintenance costs for U. S. Highway 27 are likely to increase as a result of increased road wear from the additional trucks transporting diverted rail freight over the affected sections.
2. At the present, none of the six structures located on the affected sections of U. S. Highway 27 have been classified as deficient bridges according to information compiled by the Bridge Design Department of the Indiana State Highway Commission. Five of the six have been built within the past eleven years, and each appeared capable of accommodating increased numbers of heavy vehicles for several years. However, the current situation of adequate bridges may change over a period of ten years particularly if either diverted truck volumes or normal traffic growth increases to a great extent at some point during the analysis period.

3. The roadway impact of eliminating railroad service to Jennings and Jefferson counties by way of Line Numbers 589 and 590 was found to vary between individual sections for two areal highways, State Highways 7 and 56. Determined additional overlay thicknesses ranged from practically zero for several sections to a high of 0.60 inches for a 9.08-mile segment of State Highway 56 situated between Madison and Scottsburg.
4. In the 3-county study area composed of Jennings, Jefferson, and Scott counties, there are numerous bridges on State Highways 7 and 56 which are old, narrow, and structurally deficient. The bridge analysis, based on information collected by the ISHC Bridge Design Department, indicated the necessity of either replacing or repairing 10 of the 19 structures situated on affected sections of State Highways 7 and 56. Four of the other 9 bridges have been assigned an ISHC sufficiency rating of less than 75 percent, a sign of approaching physical obsolescence. Therefore, it was concluded that abandoning Line Numbers 589 and 590 would have a serious impact on the structurally deficient bridges which predominate along the 2 highways undergoing analysis.
5. With regard to traffic congestion, the use of trucks for transporting commodities to firms located in downtown Berne and Madison could result in additional congestion on major city streets of the two towns. Furthermore, additional motor carriers traveling over the

segment of State Highway 7 from North Madison to Madison, due to its poor roadway geometry, might result in problems for that facility with respect to both traffic congestion and highway safety. However, for the most part, increases in truck numbers for both of the two case study areas were limited, on the average, to three or four added motor carriers traveling a highway section each day. Increases of this magnitude are not likely to create congestion problems unless seasonal fluctuations which cause the number of additional trucks to exceed the average occur in one of the case study areas.

6. Costs incurred from resurfacing those pavement sections which would be affected to the greatest extent by railroad abandonment were determined for the second case study area. The capital outlays contained in Table 20 are in addition to the normal resurfacing expenditures which would be required under conditions of normal traffic growth and no railroad freight diversion. Costs of repaving two highway sections, one section located along each highway undergoing analysis, were computed for the added thicknesses of bituminous concrete overlay read from the proper impact graphs. The resurfacing expenditure for the first section, a 9.08-mile segment of State Highway 56, was computed to be $82,600. The corresponding capital outlay for the second section, a 15.14-mile portion of State Highway 7, was determined to be $62,600. The above cost figures were based on the 1973 average bid price of asphaltic

concrete resurfacing for the state of Indiana, and they provide a first approximation of the financial impact on local highways of abandoning Line Numbers 589 and 590.

PART FOUR

CONCLUSION

SUMMARY AND RESULTS OF THE RESEARCH EFFORT

This research effort has addressed the problem of possible effects of railroad abandonment on rural highways and bridges. The project required a synthesis of data and information for the two largest modes of freight transportation within the United States - the railroad and the trucking industries. Because the overall goal for either national, state, or local transportation policy should involve the minimization of total resource consumption in goods movement, this research effort was concerned with the public costs associated with a highway's providing equivalent service to a marginal railroad facility. By using previously developed procedures for determining the costs of upgrading a light-density rail line, in conjunction with the methodology presented in this report for assessing the financial needs of improving a parallel highway if abandonment is implemented, governmental agencies can compare the public costs associated with the two modes, exclusive of social, environmental, and energy considerations. The following paragraphs review the steps taken in this project plus its major results.

Following a review of the reference material pertaining to the railroad reorganization process in the Northeast and Midwest, areas within the state of Indiana in danger of losing direct rail service were delineated. Rather than conduct a broad, macroscopic assessment of railroad abandonment's impact on Indiana's highways, it was decided to select two areas which possessed rail lines having relatively large rail car

volumes as case studies. The two selected rail segments were: 1) the portion of USRA Line Number 429 from Decatur, Indiana to Portland, Indiana, and 2) USRA Line Numbers 589 and 590 situated between the cities of North Vernon, Indiana and Madison, Indiana. Railroad shipping information for the two case study lines was obtained from the Penn Central Traffic Tapes located at Indiana University's Center of Urban and Regional Analysis. In addition, in order to ascertain what transportation alternatives to direct rail service were being considered by railroad users in the two affected areas, thirty-three shippers in Adams, Jay, Jennings, and Jefferson counties were personally interviewed.

The results of the railroad user survey for the Decatur to Portland and North Vernon to Madison branch lines were highly informative. It was observed that a significant shift from rail transportation to motor carriers had already occurred in the two case study areas and that several firms were utilizing trucks for even long-distance commodity movements. A second observation involved the concern expressed by shippers in Jefferson County with regard to the ability of nearby deficient bridges to accommodate the increased truck volumes resulting from service discontinuance on Line Numbers 589 and 590. From the interviews conducted in Adams and Jay counties, it was learned that elevator operators in this area valued the service qualities of truck transportation above those being offered by Line Number 429. The security of truck transportation was found to add a value which elevator operators are willing to pay for in exchange for a decrease in price received. The final conclusion reached from the interviews involved the shippers' expressed desire for direct rail accessibility despite the fact that many had discontinued use of the mode. Shippers in the two case study areas were observed to fear the loss of flexibility associated with branch line abandonment.

Methodology

After all the necessary railroad and highway information had been gathered for the two study regions, it was decided to develop a methodology for evaluating the impact of railroad abandonment on highway facilities and to use the aforementioned areas as working examples of the adopted procedure. It was felt that the development of a methodology which could be employed by local rail user groups or state and local governments for measuring the highway impact of railroad abandonment represented a valuable contribution to research related to intermodal substitutability.

The methodology developed by this study encompasses procedures to be employed for determining abandonment's impact on both highway pavements and bridges. The adopted procedure related to possible effects on pavement serviceability was based on pavement design procedures which have been developed by the American Association of State Highway Officials and the U. S. Army Corps of Engineers. By using these design procedures as a foundation, impact formulas were developed which express rail service discontinuance's impact on a rural highway in terms of additional thickness of asphaltic concrete overlay. This additional amount of flexible overlay would be required to accommodate the increased numbers of heavily-loaded commercial vehicles resulting from a rail line's closing. In order to minimize the number of computations required in employing the highway pavement procedure, graphs were prepared that would provide directly the amount of additional bituminous concrete overlay.

The procedure concerned with possible effects of railroad abandonment on rural highway bridges utilizes information which has been gathered by several agencies. By analyzing data obtained from these secondary sources

in conjunction with personal inspection of bridges likely to be affected, it becomes possible to identify those structures whose physical deficiencies pose a serious impediment to over-the-road transportation of goods formerly moved via the railroad. In addition to the aforementioned procedures, the methodology developed by this study recommends techniques to be used in meeting the data requirements of the evaluative system and explains a means of determining the financial impact of a branch line's closure on affected rural highways.

Following development of the methodology for evaluating railroad abandonment's impact on rural highways, the two case study areas were employed as procedural demonstrations. The results obtained from the two working examples were interesting. It was observed that the structural strength of the pavement of U. S. Highway 27, a parallel highway to Line Number 429 in the first case study area, should be sufficient to accommodate the added truck traffic due to rail freight diversion. On the other hand, the impact on highway pavements of State Highways 7 and 56 in the second study region ranged from practically zero for several sections to a high of 0.60 inches of additional asphaltic concrete overlay for a 9.08-mile segment of State Highway 56 between Madison and Scottsburg.

With regard to bridge conditions, it was found that none of the six structures located on U. S. Highway 27 from Decatur to Portland have been currently classified as deficient bridges according to data compiled by the ISHC Bridge Design Department. Conversely, it was revealed in the bridge analysis for the second study region composed of Jennings, Jefferson, and Scott counties that ten of the nineteen structures situated on affected sections of State Highways 7 and 56 are in

need of either replacement or repair based upon ISHC structure information.

Because abandonment's impact was relatively significant in the second case study, public costs incurred from resurfacing those pavement sections that would be affected to the greatest extent were computed. These costs do not reflect annual highway and bridge maintenance expenditures; thus, the figures represent only a first approximation to the financial impact of abandoning Line Numbers 589 and 590. The added cost of resurfacing a 9.08-mile segment of State Highway 56 was computed to be $82,600 while the corresponding capital outlay for a 15.14-mile section of State Highway 7 was determined to be $62,600.

In conclusion, the results obtained from the aforementioned working examples should not be construed as being indicative of abandonment's impact on highways in other rural areas. Because highway and bridge characteristics will certainly vary from one area to another, it becomes necessary to conduct an area specific analysis. Through the aid of the methodology developed by this study, this analysis can now be more easily accomplished.

RECOMMENDATIONS FOR FURTHER RESEARCH

The case studies conducted by this research effort were concerned primarily with the impact of railroad abandonment on State and U. S. Highways. A logical extension to this project would involve the application of the adopted methodology to county roads and bridges which could be forced to assume additional truck traffic as a result of branch line abandonment. Unpaved, gravel, or low surface type roads are considered generally to be inadequate to carry frequent heavy truck traffic and could thus limit the regular flow of goods to and from rural areas. Furthermore, county governments are presently receiving decreasing amounts of Federal financial aid for county highway reconstruction and maintenance. In Indiana, over 9,500 county bridges were classified as being unsatisfactory according to a special study conducted by the Highway Extension and Research Project for Indiana Counties (21). Thus, an investigation of the severity of railroad abandonment's impact on county roads and bridges, by using an approach similar to the one presented in this report, would appear to be a worthwhile endeavor.

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APPENDICES

APPENDIX A

APPENDIX A

AASHO Pavement Design Nomographs

The following four design nomographs were taken from the AASHO Interim Guide for Design of Pavement Structures. The charts can be used for determining concrete slab thicknesses or design structural numbers depending upon the type of pavement structure and the assumed terminal serviceability level.

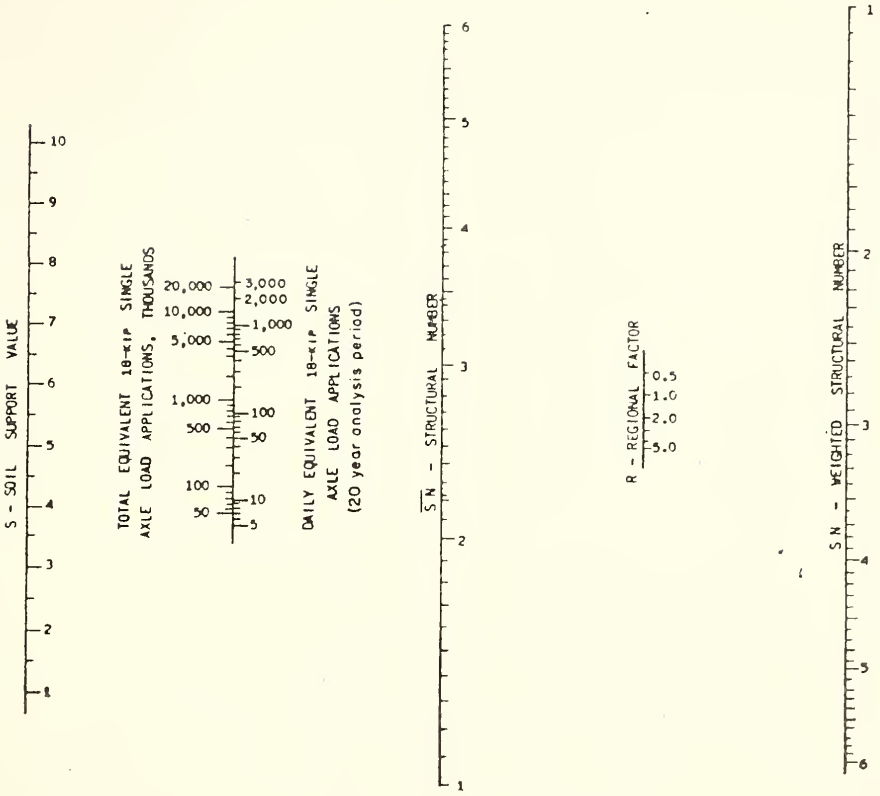


FIGURE 27. DESIGN CHART FOR FLEXIBLE PAVEMENTS, $P_t = 2.5$

FIGURE 28. DESIGN CHART FOR FLEXIBLE PAVEMENTS, P_t=2.0

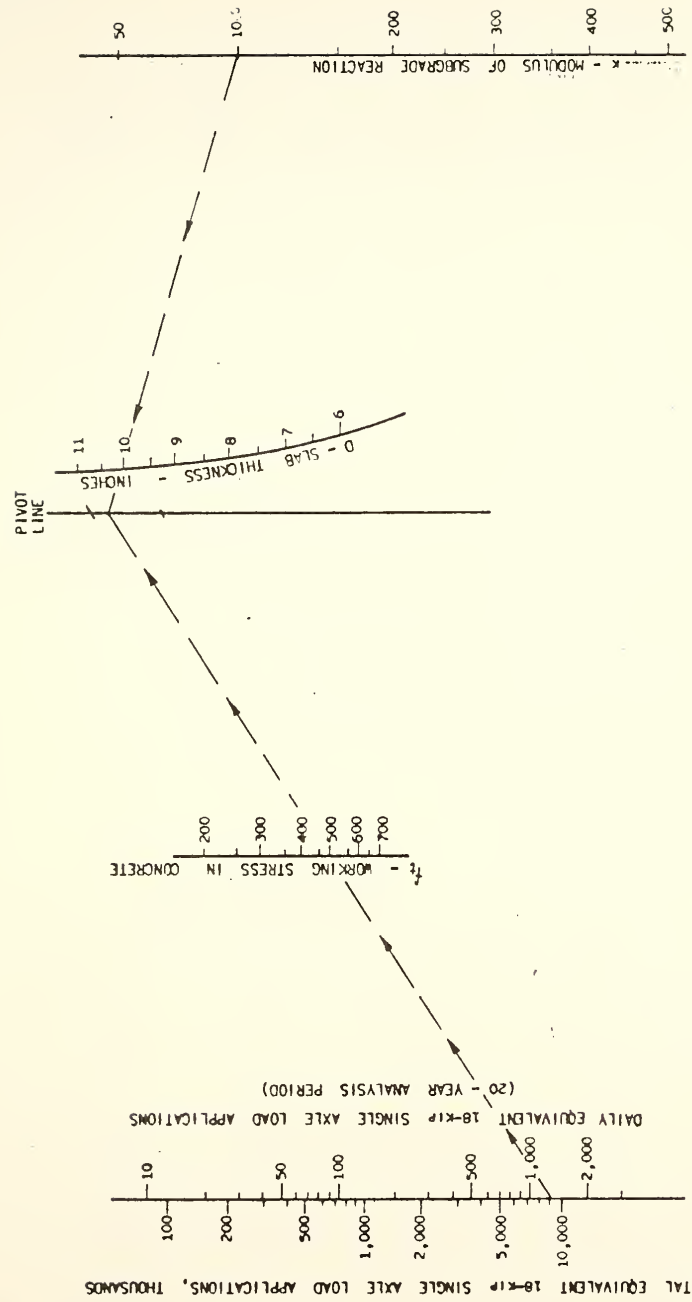


FIGURE 29. DESIGN CHART FOR RIGID PAVEMENTS, P_t=2.5

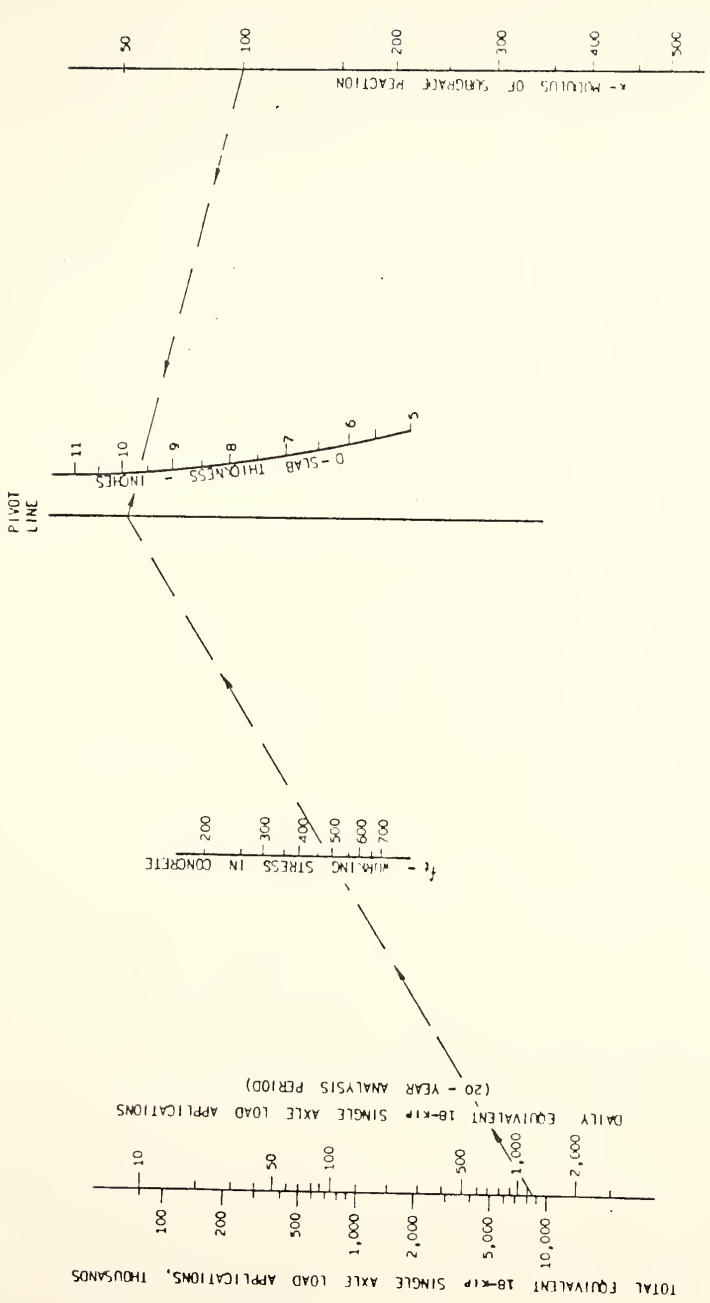


FIGURE 30. DESIGN CHART FOR RIGID PAVEMENTS, P_t=2.0

APPENDIX B

APPENDIX B

AASHO Traffic Equivalency Factors

The following four tables taken from the AASHO Interim Guide for Design of Pavement Structures contain equivalency factors which can be employed to convert mixed traffic of various vehicle types to an equivalent number of 18-kip single-axle load applications.

TABLE 21. TRAFFIC EQUIVALENCY FACTORS FOR FLEXIBLE PAVEMENTS, $P_t = 2.5$

Single Axles, $p_t = 2.5$

Axle Load, Kips	Structural Number, SN					
	1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.003	0.003	0.002
6	0.01	0.02	0.02	0.01	0.01	0.01
8	0.03	0.05	0.05	0.04	0.03	0.03
10	0.08	0.10	0.12	0.10	0.09	0.08
12	0.17	0.20	0.23	0.21	0.19	0.18
14	0.33	0.36	0.40	0.39	0.36	0.34
16	0.59	0.61	0.65	0.65	0.62	0.61
18	1.00	1.00	1.00	1.00	1.00	1.00
20	2.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.31	9.55	7.94	6.83	6.97	7.79
32	13.90	12.82	10.52	8.85	8.88	9.95
34	18.41	16.94	13.74	11.34	11.18	12.51
36	24.02	22.04	17.73	14.38	13.93	15.50
38	30.90	28.30	22.61	18.06	17.20	18.98
40	39.26	35.89	28.51	22.50	21.08	23.04

Traffic Equivalence Factors, Flexible Pavement

Tandem Axles, $p_t = 2.5$

Axle Load, Kips	Structural Number, SN					
	1	2	3	4	5	6
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.02	0.02	0.02	0.02	0.01	0.01
14	0.03	0.04	0.04	0.03	0.03	0.02
16	0.04	0.07	0.07	0.06	0.05	0.04
18	0.07	0.10	0.11	0.09	0.08	0.07
20	0.11	0.14	0.16	0.14	0.12	0.11
22	0.16	0.20	0.23	0.21	0.18	0.17
24	0.23	0.27	0.31	0.29	0.26	0.24
26	0.33	0.37	0.42	0.40	0.36	0.34
28	0.45	0.49	0.55	0.53	0.50	0.47
30	0.61	0.65	0.70	0.70	0.66	0.63
32	0.81	0.84	0.89	0.89	0.86	0.83
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.08	4.80	4.25	3.98	4.17	4.49

TABLE 22. TRAFFIC EQUIVALENCY FACTORS FOR FLEXIBLE PAVEMENTS, $P_t = 2.0$

Single Axles, $p_t = 2.0$

Axle Load Kips	Structural Number, SN					
	1	2	3	4	5	6
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.003	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.04	0.04	0.03	0.03	0.03
10	0.08	0.08	0.09	0.08	0.08	0.08
12	0.16	0.18	0.19	0.18	0.17	0.17
14	0.32	0.34	0.35	0.35	0.34	0.33
16	0.59	0.60	0.61	0.61	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.60
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.38	10.03	9.24	8.65	8.73	9.17
32	14.00	13.51	12.37	11.46	11.48	12.17
34	18.55	17.87	16.30	14.97	14.87	15.63
36	24.20	23.30	21.16	19.28	19.02	19.93
38	31.14	29.95	27.12	24.55	24.03	25.10
40	39.57	38.02	34.34	30.92	30.04	31.25

Traffic Equivalence Factors, Flexible Pavement

Tandem Axles, $p_t = 2.0$

Axle Load Kips	Structural Number, SN					
	1	2	3	4	6	8
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.01	0.01	0.01
14	0.02	0.03	0.03	0.03	0.02	0.02
16	0.04	0.05	0.05	0.05	0.04	0.04
18	0.07	0.08	0.08	0.08	0.07	0.07
20	0.10	0.12	0.12	0.12	0.11	0.10
22	0.16	0.17	0.18	0.17	0.16	0.16
24	0.23	0.24	0.26	0.25	0.24	0.23
26	0.32	0.34	0.36	0.35	0.34	0.33
28	0.45	0.46	0.49	0.48	0.47	0.46
30	0.61	0.62	0.65	0.64	0.63	0.62
32	0.81	0.82	0.84	0.84	0.83	0.82
34	1.06	1.07	1.08	1.08	1.08	1.07
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.76	1.75	1.73	1.72	1.73	1.74
40	2.22	2.19	2.15	2.13	2.16	2.18
42	2.77	2.73	2.64	2.62	2.66	2.70
44	3.42	3.36	3.23	3.18	3.24	3.31
46	4.20	4.11	3.92	3.83	3.91	4.02
48	5.10	4.98	4.72	4.58	4.68	4.83

TABLE 23. TRAFFIC EQUIVALENCY FACTORS FOR RIGID PAVEMENTS, $P_t = 2.5$

Single Axles, $p_t = 2.5$

Axle Load, Kips	D Slab Thickness inches					
	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.003	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.04	0.04	0.03	0.03	0.03	0.03
10	0.10	0.09	0.08	0.08	0.08	0.08
12	0.20	0.19	0.18	0.18	0.18	0.17
14	0.38	0.36	0.35	0.34	0.34	0.34
16	0.63	0.62	0.61	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.51	1.52	1.55	1.57	1.58	1.58
22	2.21	2.20	2.28	2.34	2.38	2.40
24	3.16	3.10	3.23	3.36	3.45	3.50
26	4.41	4.26	4.42	4.67	4.85	4.95
28	6.05	5.76	5.92	6.29	6.61	6.81
30	8.16	7.67	7.79	8.28	8.79	9.14
32	10.81	10.06	10.10	10.70	11.43	11.99
34	14.12	13.04	12.94	13.62	14.59	15.43
36	18.20	16.69	16.41	17.12	18.33	19.52
38	23.15	21.14	20.61	21.31	22.74	24.31
40	29.11	26.49	25.65	26.29	27.91	29.90

Traffic Equivalence Factors, Rigid Pavement

Tandem Axles, $p_t = 2.5$

Axle Load, Kips	D - Slab Thickness - inches					
	6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.06	0.05	0.05	0.05	0.05	0.05
16	0.10	0.09	0.08	0.08	0.08	0.08
18	0.16	0.14	0.14	0.13	0.13	0.13
20	0.23	0.22	0.21	0.21	0.20	0.20
22	0.34	0.32	0.31	0.31	0.30	0.30
24	0.48	0.46	0.45	0.44	0.44	0.44
26	0.64	0.64	0.63	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.11	1.12	1.13	1.14	1.14	1.14
32	1.43	1.44	1.47	1.49	1.50	1.51
34	1.82	1.82	1.87	1.92	1.95	1.96
36	2.29	2.27	2.35	2.43	2.48	2.51
38	2.85	2.80	2.91	3.04	3.12	3.16
40	3.52	3.42	3.55	3.74	3.87	3.94
42	4.32	4.16	4.30	4.55	4.74	4.86
44	5.26	5.01	5.16	5.48	5.75	5.92
46	6.36	6.01	6.14	6.53	6.90	7.14
48	7.64	7.16	7.27	7.73	8.21	8.55

TABLE 24. TRAFFIC EQUIVALENCY FACTORS FOR RIGID PAVEMENTS, P_t=2.0

Single Axles, p_t = 2.0

Axle Load Kips	D - Slab Thickness - inches					
	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.03	0.03	0.03	0.03	0.03
10	0.09	0.08	0.08	0.08	0.08	0.08
12	0.19	0.18	0.18	0.18	0.17	0.17
14	0.35	0.35	0.34	0.34	0.34	0.34
16	0.61	0.61	0.60	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.55	1.56	1.57	1.58	1.58	1.59
22	2.32	2.32	2.35	2.38	2.40	2.41
24	3.37	3.34	3.40	3.47	3.51	3.53
26	4.76	4.69	4.77	4.88	4.97	5.02
28	6.59	6.44	6.52	6.70	6.85	6.94
30	8.92	8.68	8.74	8.98	9.23	9.39
32	11.87	11.49	11.51	11.82	12.17	12.44
34	15.55	15.00	14.95	15.30	15.78	16.18
36	20.07	19.30	19.16	19.53	20.14	20.71
38	25.56	34.54	24.26	24.63	25.36	26.14
40	32.18	30.85	30.41	30.75	31.58	32.57

Traffic Equivalence Factors, Rigid Pavement

Tandem Axles, p_t = 2.0

Axle Load, Kips	D - Slab Thickness - inches					
	6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.05	0.05	0.05	0.05	0.05	0.05
16	0.09	0.08	0.08	0.08	0.08	0.08
18	0.14	0.14	0.13	0.13	0.13	0.13
20	0.22	0.21	0.21	0.20	0.20	0.20
22	0.32	0.31	0.31	0.30	0.30	0.30
24	0.45	0.45	0.44	0.44	0.44	0.44
26	0.63	0.64	0.62	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.13	1.13	1.14	1.14	1.14	1.14
32	1.48	1.45	1.49	1.50	1.51	1.51
34	1.91	1.90	1.93	1.95	1.96	1.97
36	2.42	2.41	2.45	2.49	2.51	2.52
38	3.04	3.02	3.07	3.13	3.17	3.19
40	3.79	3.74	3.80	3.89	3.95	3.98
42	4.67	4.59	4.66	4.78	4.87	4.93
44	5.72	5.59	5.67	5.82	5.95	6.03
46	6.94	6.76	6.83	7.02	7.20	7.31
48	8.36	8.12	8.17	8.40	8.63	8.79

APPENDIX C

APPENDIX C

Determination of Soil Support Values for Indiana Highways

By employing Figure 31 in conjunction with Table 25, user agencies in Indiana can determine a soil support value (S) for any highway section being studied for possible effects of railroad abandonment.

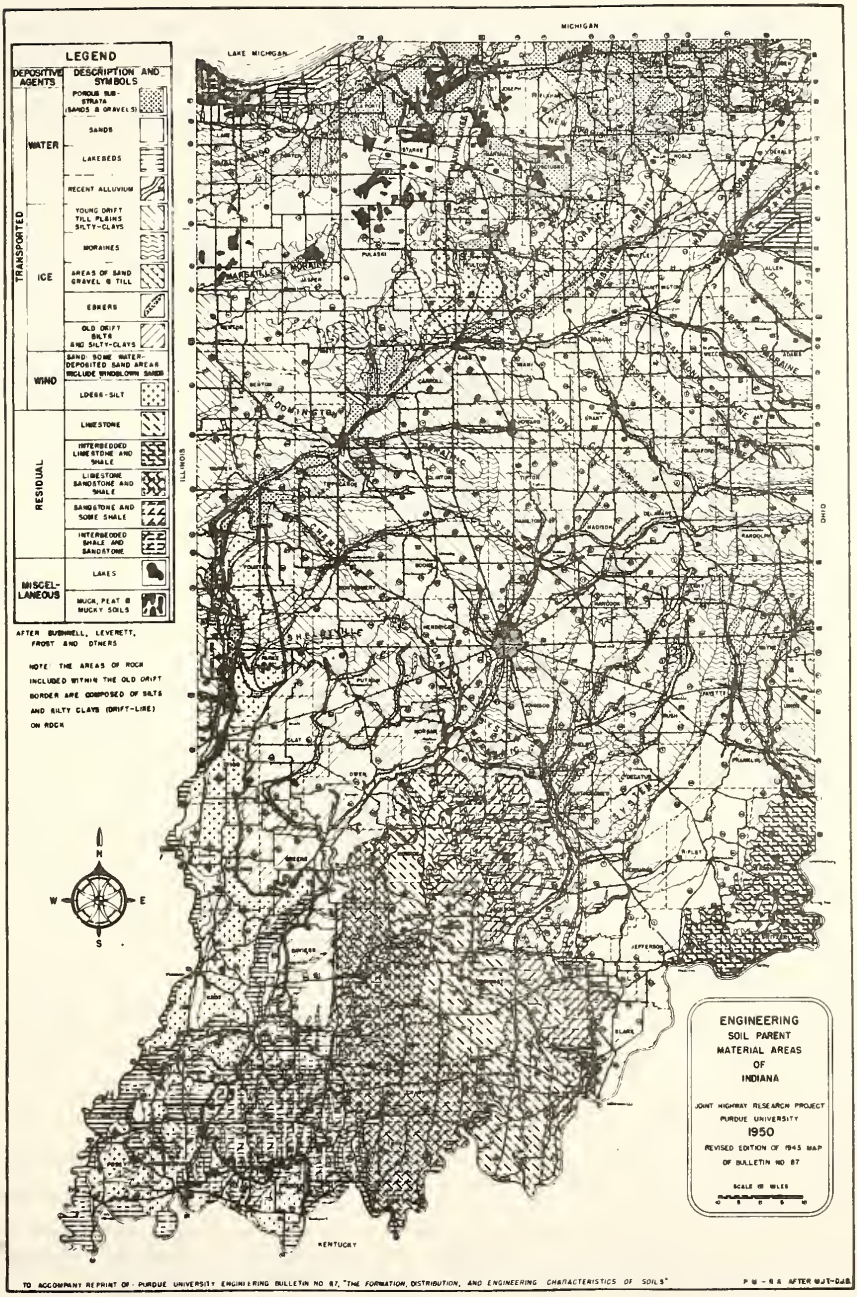


FIGURE 31. MAP FOR DETERMINING MAJOR SOIL UNITS

Table 25. Soil Support Values for the Major Soil Units of Indiana

		Major Soil Unit	Soil Support Value
Water Transported	(1)	Porous Substrata (Sands and Gravels)	6.8
	(2a)	Sands (Except Kankakee Sands)	6.2
	(2b)	Kankakee Sands	5.6
	(3)	Lakebeds	4.0
	(4)	Recent Alluvium	4.6
Ice Transported	(5)	Young Drift Till Plains (Silty-Clays)	4.9
	(6)	Moraines	4.9
	(7)	Areas of Sand, Gravel, and Till	5.9
	(8)	Eskers	6.7
	(9)	Old Drift Silts and Silty-Clays	5.0
Wind Transported	(10)	Sand: Some Water-Deposited Sand Areas Include Windblown Sands	6.0
	(11)	Loess-Silt	5.3
Residual	(12)	Limestone	5.1
	(13)	Interbedded Limestone and Shale	4.7
	(14)	Limestone, Sandstone, and Shale	5.0
	(15)	Sandstone and Some Shale	5.4
	(16)	Interbedded Shale and Sandstone	4.8
Misc.	(17)	Muck, Peat, and Mucky Soils	2.7

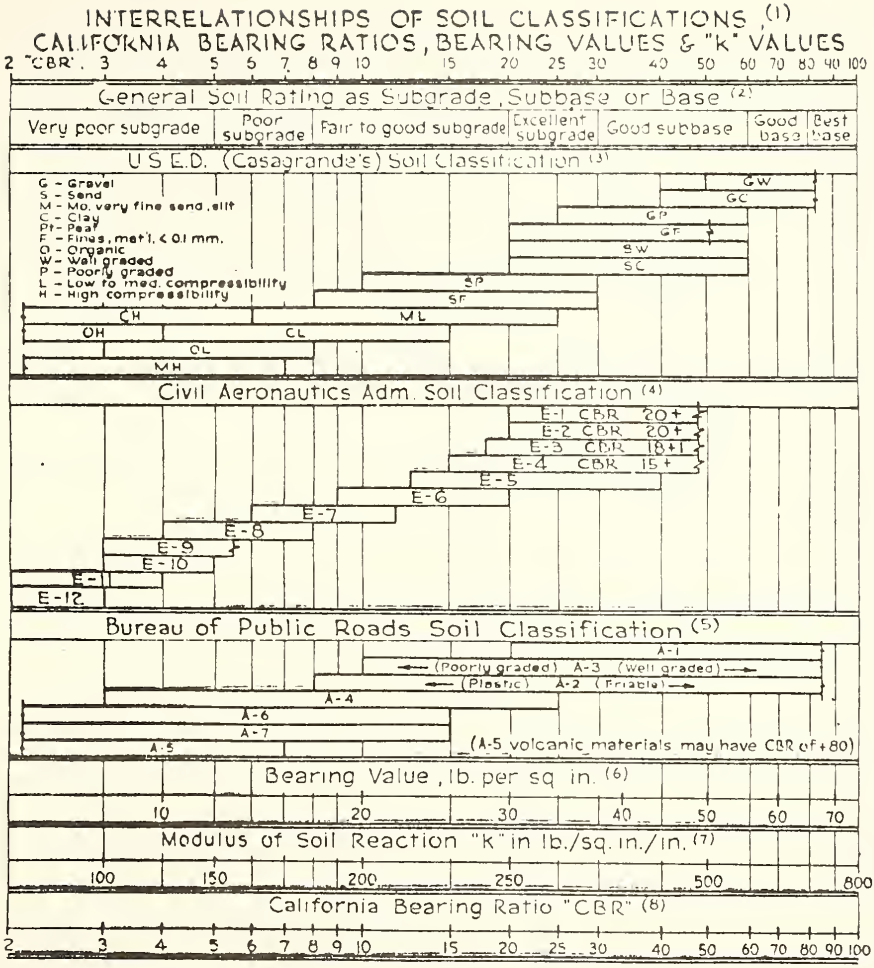
Source: Edgar P. Ulbricht, "A Method for Comparing Alternate Pavement Designs" (Unpublished MSCE Thesis, Purdue University, 1967), Table 18, p. 108.

APPENDIX D

APPENDIX D

Determination of Values for the Modulus of Subgrade Reaction

Figure 32 which was taken from NCHRP Report 128, "Evaluation of AASHO Interim Guides for Design of Pavement Structures", exhibits interrelationships between the modulus of subgrade reaction (k) and various soil parameters. Figure 33 shows the correlation between the k-value and the R-value, and it was taken from the Portland Cement Association's 1963 publication, The Design of Concrete Pavements for City Streets.



(1) All interrelationships are very approximate. Actual tests are required to determine "CBR", "K", etc.
(2) See "Foundations for Flexible Pavements" by O.J. Porter, 22nd Annual Meeting, Highway Research Board 1942, for basic idea
(3) Relationships from Engineering Mannual, Chapter XX, March 1943, War Department, Office of Chief of Engineers See also, "Soil Tests for Design of Runway Pavements" by Middlebrooks & Bertram, 22nd An Mtg H.R.B. 1942
(4) CBR values estimated from old CAA classification system.
(5) See item (3). A-6 and A-7 soils cut off at CBR-15, rather than 25 as indicated in Chapter XX
(6) See second reference of item (3), page 184. Bearing values at 0.1 in deflection, bearing area not given.
(7) See item (3). "K" is factor used in Westergaard's Analysis for thickness of portland cement concrete pavement
(8) See items (2) and (3)

FIGURE 32. INTERRELATIONSHIPS BETWEEN VARIOUS SOIL PARAMETERS

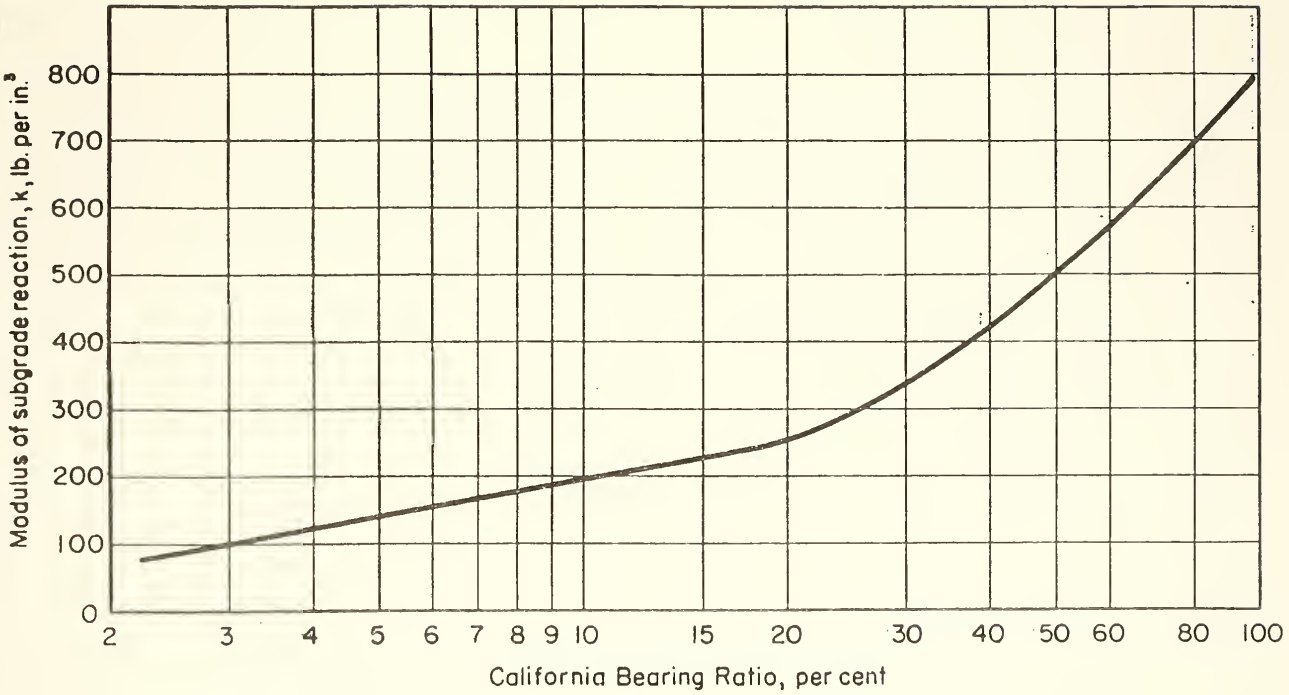


FIGURE 33. RELATIONSHIP BETWEEN CALIFORNIA BEARING RATIO AND MODULUS OF SUBGRADE REACTION

APPENDIX E

APPENDIX E

The Rail User Survey

Appendix E contains a copy of the letter which was sent to all railroad users selected for interviews and the questionnaire form that was used to record a shipper's answers and comments.

Copy of Letter Mailed to Rail Users

Dear Sir:

I am currently a Graduate Assistant in Research at Purdue University, School of Civil Engineering. I am involved in a research project, to be used for my MSCE thesis, concerned with the impact of rail abandonment on the highway system of Indiana. As one phase of this study, I am interviewing a group of rail users as a means of determining possible alternative shipping patterns which would arise from rail service discontinuance. This interview, requiring only ten to fifteen minutes, will involve my asking you several questions about alternative shipping patterns necessitated by branch line abandonment.

A stamped, self-addressed post card has been enclosed with this letter. Please name the person with whom I will be meeting, his address, and telephone number. If there are no objections to the time and date stated on the card, please return the card to me in order that I may know our meeting has been confirmed. However, if this time and date is unsatisfactory, please indicate a more suitable time and/or date for the interview and return the card to me.

I realize that your firm, as a user located on a rail line being analyzed for possible abandonment, has been subjected to numerous bothersome questionnaires about your rail activities. However, I sincerely hope that you will allow me the opportunity for this short discussion as the information should prove valuable for my research.

Thank you for your time and cooperation, and I look forward to meeting a representative from your firm soon.

Rail User Questionnaire

I. Basic Information

A. Railroad Station _____
B. Name of Business _____
C. Address _____
_____ Telephone No. _____
D. Years in business at this location _____
E. Name and title of person supplying information ____
_____ Telephone No. _____
F. What is the nature of your business' activities?

Farm Inputs		Farm Outputs	
1. Fuel	_____	6. Grain	_____
2. Fertilizer	_____	7. Other crops	_____
3. Feed	_____	8. Other (Specify)	___
4. Farm Implements	_____		_____
5. Other (Specify)	_____		
_____			

Industrial

9. Metal products _____
10. Lumber _____
11. Food processing _____
12. Equipment _____
13. Other (Specify) _____
_____

II. Impact

A. Have possible changes in rail service caused you to explore business alternatives? Yes _____ No _____
(If "No" skip to question C)
B. What alternative business action would you take if rail service was discontinued?

_____1. Go out of business.
_____2. Reduce business size and/or employment.
_____3. Relocate on a viable rail line.
_____4. Switch to trucks exclusively.
_____5. Truck to/from the closest rail point.
_____6. Other (Please explain) _____
_____
_____
_____

C. If trucking is an alternative to discontinued rail service, what major routes or highways (Interstate, U.S., or State routes) would be used for: (Show route numbers)

1. Shipping products _____
2. Receiving goods _____

D. If trucking is an alternative to discontinued rail service, what local roads (County roads or City streets) would be most used in reaching the nearest major routes, mentioned in question C above, for: (Show street or road names)

1. Shipping products _____
2. Receiving goods _____

E. Please specify any adverse road, street, or bridge conditions that would be encountered in using trucking as an alternative to discontinued rail service. (Conditions such as inadequate traffic capacity, road alignment, or road width; low clearances under bridges or low load limits on bridges; poor pavement or drainage characteristics).

1. Shipping products _____
2. Receiving goods _____

F. Do you ship or receive materials (or commodities) that by their nature (dimensions, density, etc.) are highly restrictive to rail transportation? If Yes, complete the following.

Material or Commodity	Shipments/Year	Explanation

G. Do you know of any federal, state, or local regulations and/or labor relations restrictions which regulate the mode of transporting any commodity shipped or received? If Yes, complete the following.

Commodity	Restriction

H. Many shippers anticipate changes in rail shipments in 1975-76 as a result of new markets, new facilities, new products and new suppliers. Will your total rail shipments change substantially in 1975-76 from the 1973 level of activity.

Change _____ Remain Unchanged _____

If a change will occur or has already occurred, please provide the following information:

Commodity	Change over 1973 in Tons Increase/Decrease	Reason
	/	
	/	
	/	
	/	

III. Comments:

IV. Rail Shipping Information

A. Please provide the following information on outbound rail shipments for the year 1973.

Commodity	Tons	Carloads	Type of Car

B. Please provide the following information on inbound rail shipments for the year 1973.

Commodity	Tons	Carloads	Type of Car

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